FISCAL YEAR 1985 DEPARTMENT OF ENERGY AUTHORIZATION

(Nuclear Fission R&D and Waste Management)

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
ENERGY RESEARCH AND PRODUCTION

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

NINETY-EIGHTH CONGRESS

SECOND SESSION

FEBRUARY 7, 8, 9, 1984

[No. 89]

VOLUME IV

Printed for the use of the
Committee on Science and Technology

U.S. GOVERNMENT PRINTING OFFICE
33-675 O WASHINGTON : 1984

H701-26

COMMITTEE ON SCIENCE AND TECHNOLOGY

DON FUQUA, Florida, *Chairman*

ROBERT A. ROE, New Jersey
GEORGE E. BROWN, Jr., California
JAMES H. SCHEUER, New York
RICHARD L. OTTINGER, New York
TOM HARKIN, Iowa
MARILYN LLOYD, Tennessee
DOUG WALGREN, Pennsylvania
DAN GLICKMAN, Kansas
ALBERT GORE, Jr., Tennessee
ROBERT A. YOUNG, Missouri
HAROLD L. VOLKMER, Missouri
BILL NELSON, Florida
STAN LUNDINE, New York
RALPH M. HALL, Texas
DAVE McCURDY, Oklahoma
MERVYN M. DYMALLY, California
PAUL SIMON, Illinois
NORMAN Y. MINETA, California
RICHARD J. DURBIN, Illinois
MICHAEL A. ANDREWS, Texas
BUDDY MacKAY, Florida
TIM VALENTINE, North Carolina
HARRY M. REID, Nevada
ROBERT G. TORRICELLI, New Jersey
FREDERICK C. BOUCHER, Virginia

LARRY WINN, Jr., Kansas
MANUEL LUJAN, Jr., New Mexico
ROBERT S. WALKER, Pennsylvania
WILLIAM CARNEY, New York
F. JAMES SENSENBRENNER, Jr., Wisconsin
JUDD GREGG, New Hampshire
RAYMOND J. McGRATH, New York
JOE SKEEN, New Mexico
CLAUDINE SCHNEIDER, Rhode Island
BILL LOWERY, California
ROD CHANDLER, Washington
HERBERT H. BATEMAN, Virginia
SHERWOOD L. BOEHLERT, New York
ALFRED A. (AL) McCANDLESS, California
TOM LEWIS, Florida

Harold P. Hanson, *Executive Director*
Robert C. Ketcham, *General Counsel*
Regina A. Davis, *Chief Clerk*
David S. Jeffery, *Minority Staff Director*

Subcommittee on Energy Research and Production

MARILYN LLOYD, Tennessee, *Chairman*

ROBERT A. ROE, New Jersey
ROBERT A. YOUNG, Missouri
STAN LUNDINE, New York
RICHARD OTTINGER, New York
RALPH M. HALL, Texas
TIM VALENTINE, North Carolina

ROBERT S. WALKER, Pennsylvania
ROD CHANDLER, Washington
MANUEL LUJAN, Jr., New Mexico
BILL LOWERY, California

John V. Dugan, Jr., *Staff Director*
Louis Ventre, Jr., *Counsel*
William T. Harvey, *Minority Energy Coordinator*

CONTENTS

WITNESSES

	Page
February 7, 1984:	
Dr. Alvin M. Weinberg, Institute for Energy Analysis, Oak Ridge Associated Universities, Oak Ridge, Tenn	2
Dr. Richard K. Lester, associate professor of nuclear engineering, Massachusetts Institute of Technology	143
Charles F. Jones, president, NUS Corp., Gaithersburg, Md	157
Frederick L. Webber, executive vice president, Edison Electric Institute	168
Dr. Ersel A. Evans, technical director, Hanford Engineering Development Laboratory, Westinghouse Hanford Co., Richland, Wash	188
Donald B. Trauger, Associate Director for Nuclear and Engineering Technologies, Oak Ridge National Laboratory, Oak Ridge, Tenn	196
Paul R. Kasten, Director, Gas-Cooled Reactor Programs, Oak Ridge National Laboratory, Oak Ridge, Tenn	201
George F. Dilworth, Assistant Manager, Tennessee Valley Authority, Knoxville, Tenn	229
H. James Dager, vice president of engineering, projects and construction, Florida Power & Light Co	237
Dr. John H. Gibbons, Director, Office of Technology Assessment, accompanied by Dr. Alan Crane, senior associate	244
Dr. Carl E. Behrens, specialist in energy policy, Congressional Research Service	262
February 8, 1984:	
Dr. Shelby T. Brewer, Assistant Secretary for Nuclear Energy, Department of Energy	308
Dr. Harold M. Agnew, president, GA Technologies, Inc	377
Dr. Charles L. Storrs, director of advanced development, Nuclear Power Systems, Combustion Engineering, Inc	393
Richard F. Walker, president and chief executive officer, Public Services Co. of Colorado	399
Dr. W. Howard Arnold, general manager, Advanced Energy Systems Division, Westinghouse Electric Corp	410
Robert O. Williams, Jr., president, Energy Systems Group, Rockwell International	471
Dr. Bertram Wolfe, vice president and general manager, Nuclear Fuels and Special Products Division, General Electric Co	479
Dr. Charles E. Till, Associate Laboratory Director, Research and Development, Argonne National Laboratory	487
John C. Young, president, International Energy Associates Ltd	506
Dr. William E. Wright, Director, DOE-NASA-DOD Space Nuclear Power Program, Defense Advanced Research Projects Agency	612
Dr. Jay E. Boudreau, Deputy Associate Director, Nuclear Programs, Los Alamos National Laboratory	622
February 9, 1984:	
Hon. James F. McNulty, Jr., a Representative in Congress from the State of Arizona	643
Donald B. Mausshardt, Deputy Director, Office of Nuclear Material Safety and Safeguards, Nuclear Regulatory Commission, accompanied by Richard Cunningham and by Robert Browning	656
Sherwood H. Smith, Jr., chief executive officer, Carolina Power & Light, representing Edison Electric Institute	671
Leo P. Duffy, general manager, Westinghouse Waste Technology Services Division	721

February 9, 1984—Continued Page
Warren P. Chernock, vice president, development, Nuclear Power Systems, C-E Power Systems, Combustion Engineering Inc 747
Michael J. Lawrence, Acting Director, Office of Civilian Radioactive Waste Management, Department of Energy 773
Dr. Franklin E. Coffman, Director, Office of Terminal Waste Disposal and Remedial Action, Department of Energy 817

APPENDIX

SUPPLEMENTAL QUESTIONS AND ANSWERS FOR THE RECORD

FEBRUARY 7

Dr. Alvin M. Weinberg, Institute for Energy Analysis 847
Dr. Richard K. Lester, Massachusetts Institute of Technology 849
Frederick L. Webber, Edison Electric Institute 885
Dr. Ersel A. Evans, Westinghouse Hanford Co 888
Dr. Donald B. Trauger, Oak Ridge National Laboratory 893
Paul R. Kasten, Oak Ridge National Laboratory 898
George Dilworth, Tennessee Valley Authority 901
Jim Dager, Florida Power & Light Co 905
Dr. John H. Gibbons, Office of Technology Assessment 933
Carl E. Behrens, Congressional Research Service 936

FEBRUARY 8

Hon. Shelby T. Brewer, Assistant Secretary for Nuclear Energy, U.S. Department of Energy 939
Dr. Harold M. Agnew, GA Technologies, Inc 954
Dr. Charles L. Storrs, Combustion Engineering, Inc 958
Richard F. Walker, Public Service Co. of Colorado 962
Dr. W. Howard Arnold, Westinghouse Electric Corp 967
R. O. Williams, Jr., Rockwell International 975
Dr. Bertram Wolfe, General Electric Co 979
Dr. Charles E. Till, Argonne National Laboratory 982
John C. Young, International Energy Associates, Ltd 989
Dr. William E. Wright, Defense Advanced Research Projects Agency 992
Dr. Jay E. Boudreau, Los Alamos National Laboratory 995

FEBRUARY 9

Nuclear Regulatory Commission 1046
Sherwood H. Smith, Jr., representing Edison Electric Institute 1077
Leo P. Duffy, Westinghouse Waste Technology Services Division 1084
Warren P. Chernock, Combustion Engineering, Inc 1090
Department of Energy—Mr. Michael Lawrence and Dr. Franklin Coffman 1094

1985 DEPARTMENT OF ENERGY AUTHORIZATION

TUESDAY, FEBRUARY 7, 1984

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Research and Production,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:07 a.m., in room 2318, Rayburn House Office Building, Hon. Marilyn Lloyd (chairperson of the subcommittee) presiding.

Present: Representatives Lloyd, Valentine, Walker, and Chandler.

Also present: Representative Morrison.

Mrs. Lloyd. The Subcommittee on Energy Research and Production will come to order.

I would like to say good morning to everyone in our audience, our participants, and members of the press, and all of you who are observers today.

Without objection, the use of recording devices will be allowed for today's hearing.

Today we should be very thankful for the opportunities which lay before us. We have a chance to restructure the nuclear R&D programs in a most positive way, so as to vastly improve the climate for the nuclear option.

We also have a chance to redistribute resources across this country's nuclear effort, so as to support the most innovative, advanced reactor designs. We must do this in a way that assures that reactors will be developed which meet tomorrow's market tests. Today's R&D should lay the groundwork for a broad variety of approaches from small and large powerplants through compact reactors for remote siting applications and space power.

We must not ignore today's realities that nuclear power, although still full of promise, is, in fact, a technology under siege. Also, no friend of this technology can fail to recognize that some of its problems are self-inflicted. Neither can we assume that advanced technology, even if successfully developed, will of itself save the nuclear option. As the OTA report released yesterday indicated, it is unlikely that we will have any new nuclear plants ordered in this century without significant changes in the manner in which the entire nuclear enterprise is conducted and regulated.

This is a time for genuine renewal, where we can chart a new course which could lead to a revitalized nuclear option. It is also time for reconciliation, when frank and open discourse among all interested parties is critical, so that we can arrive at a concensus on new emphases for the overall nuclear development program.

In that respect, I would strongly encourage the very capable national laboratories and the industry players to look at all programs in which they can bring a particular expertise. We simply cannot afford business as usual.

The first nuclear era dawned when that artificial Sun blazed over Alamagardo 40 years ago, and yet that weapons mystique was to cast a lingering shadow over civilian power development. We can share in the glory of the dawn of the second nuclear era if we confront the problems of civilian nuclear power head on and innovatively work together to devise the necessary solutions. Tomorrow will not be brighter just because we wish it so, but we certainly might view a radiant dawn if everybody pulls together.

Our first panel today is comprised of Dr. Alvin Weinberg, Dr. Richard Lester, Mr. Charles Jones, and Mr. Fred Webber.

Dr. Weinberg is certainly an old friend of ours, and he's a very distinguished scientist who has recently been involved in some studies of great interest to us.

Dr. Weinberg, I'm certainly looking forward to hearing from you, not only as my constituent but as my friend. Please proceed.

STATEMENT OF DR. ALVIN M. WEINBERG, INSTITUTE FOR ENERGY ANALYSIS, OAK RIDGE ASSOCIATED UNIVERSITIES, OAK RIDGE, TENN.

Dr. **Weinberg**. Thank you very much, Madam Chairman. I'm very grateful for this opportunity to appear before this subcommittee to express my views on the U.S. nuclear program.

As you mentioned, our Institute for Energy Analysis has recently completed a 2-year study——

Mrs. **Lloyd**. Dr. Weinberg, excuse me. I want to make sure that your microphone is on.

Dr. **Weinberg**. Is it working now?

Mrs. **Lloyd**. They say in the back of the room that it is. Thank you. I'm sorry.

Dr. **Weinberg**. Our Institute for Energy Analysis has recently completed a 2-year study of the outlook for a second nuclear era, which was sponsored by the Andrew W. Mellon Foundation. Let me just say a word about the background of the study.

Three years ago, in 1980, a David Lilienthal, who had been the first Chairman of the Atomic Energy Commission, wrote a little book called, "Atomic Energy: A New Start." In this book he called upon the nuclear technological community to come up with very forgiving, inherently safe nuclear reactors, insisting that this was the only way to salvage nuclear energy.

I reviewed that book, and at the time I said that, well, it was all very well and good for David Lilienthal, who is not a technologist, to call for the technologically impossible; namely, a totally safe reactor. I said the key really was an improvement in the institutions.

But with this grant of the Andrew Mellon Foundation, we undertook to examine whether his thesis was correct: Is it possible to invent a totally safe reactor and, if one had a totally safe reactor, would this change the whole complexion of public acceptance of nuclear energy?

I'm very pleased to say, and a bit surprised, that as a result of our 2-year study we have concluded that David Lilienthal was right; that it is possible to conceive of reactors that are probably quite practical and that are inherently safe. I would like to say a few words about some of our findings in that connection.

We discovered two such reactors that we thought fit into the category of inherently safe systems, but before speaking to those I want to insist that our study reiterated our belief, reinforced our belief, that existing reactors are very safe—especially the improved light water reactors, which we'll hear about in today's testimony by other participants—are extremely safe devices, so that anything that I say about inherently safe reactors in no way is meant to cast reflections on the degree of safety of existing reactors.

One must remember that, despite the deficiencies, despite the difficulties that we've encountered in nuclear energy, in many ways nuclear energy has been a fantastic success, 8 percent of the world's primary energy being generated by nuclear power from an energy source that 40 years ago was completely unknown—an extraordinary, fantastic success. We must always remember that.

Also, I guess I would say that in supporting these new initiatives for development of inherently safe reactors, we should keep in mind that the single most important action that's necessary throughout the world for preserving the nuclear option during the next couple of decades is the continued safe and efficient construction and operation of the present nuclear plants.

With respect to the inherently safe reactors themselves, I want to say that I strongly support the letter of November 14 to the Secretary of Energy from Don Fuqua, the chairman of this committee, and from Marilyn Lloyd, the chairman of this subcommittee. That letter recommends that the DOE fund development of inherently safe reactors.

By inherently safe reactors, we mean reactors whose safety depends not on the intervention of humans or of electromechanical devices, but instead depends on immutable, well-understood laws of physics and chemistry—so to speak, reactors whose inherent safety is transparent and patented, reactors whose safety is understandable to the man on the street, the man on the street who's been so frightened by the Three-Mile Island incident.

As I say, we were rather surprised and not a little pleased to discover two—at least two—well-thought-out ideas for inherently safe reactors: the so-called PIUS reactor being developed in Sweden by ASEA-ATOM and the modular high temperature gas reactor proposed by General Atomic Technologies in this country and by Interatom, a subsidiary of KWU in Germany.

I believe that the high temperature gas reactor will be described by several of the other panelists, and so perhaps I will devote a little bit of time on the PIUS reactor, and I have a transparency here. I take this along, and then I can talk and show the transparency.

The main idea of PIUS is twofold: first, to build the reactor in an ICBM silo basically——

Mrs. **Lloyd**. Excuse me, Dr. Weinberg. Let's give you a little bit more help so we can see this.

Dr. **Weinberg**. I think you can pretty well see that the reactor itself is built at the bottom of what, in effect, is an ICBM silo. The whole thing is immersed in a huge pool of water. The water has boron in it, and boron, of course, suppresses a chain reaction. And the essential and very ingenious idea is to have a free interface at bottom and at the top of the reactor between the borated water, which quenches the chain reaction, and the coolant water, which cools the chain reaction. And so if there's any disturbance at all in the cooling of the reactor, then this borated water rushes in, according to the laws of physics, without any intervention whatsoever; it cools the reactor; prevents it from chain reacting; and there's enough water in this ICBM silo to keep the reactor cool for about a week or so.

The Swedes came upon this very ingenious idea because, of course, they have a moratorium there, and they felt that unless the public could be made to understand that it is possible to build a reactor that had no possibility of a meltdown that they were out of business. And it is to their very great credit for having reopened a question which I suppose most of us in the chain reactor business over these 40 years had rather ignored: Is it possible to build a reactor that's inherently and completely safe? And the answer is it is, and I suppose it's fair to say, as this hearing attests, that this may not be the only way of doing it but it's a very ingenious way and one that we think deserves a very great deal of attention. I'm delighted that this hearing will open this whole question of whether David Lilienthal's admonition to the technological community and to the Government is to be taken seriously.

Well, I don't have very much time, so I shall simply summarize the points that I have in my testimony. These are expanded at great length in the report which has just come out today, and it may be that you may be able to include the 100-page report as part of the testimony that we're giving here today, but I, of course, am not able to cover that now.

Mrs. **Lloyd**. Without objection, your complete statement and report will be made a part of the record.

Dr. **Weinberg**. Thank you very much, Madam Chairman.

And to summarize, then, my main points:

No. 1, incrementally improved post-Three-Mile Island light water reactors pose very low risks to the public. However, investor risk and high and uncertain capital costs may limit their market in the United States.

Second, inherently safe reactors appear to be practicable. The development of such reactors should be undertaken to provide a technological alternative for widespread deployment in the future. If preliminary development of such systems continues to show promise, a prototype of such reactor or reactors should be built to better define operability and economics, and to prove the safety characteristics.

Three, a point that we touched upon in our longer report, but I didn't mention here: studies should be undertaken of long-term regulatory and institutional reform to allow the society to benefit from the improved nuclear technology which will be forthcoming.

In other words, the regulatory process should take account of the improvement in intrinsic safety of these reactors.

Four, the breeder program should be restructured to emphasize international cooperation and the U.S. development of innovative technology which will reduce breeder capital costs and increase inherent safety.

And, five, the above recommendations should not be pursued at the expense of reducing effort to make the present nuclear plants safe and economical. The success of the present plants is necessary to support a continuation of the nuclear option.

As I say, I have every confidence that in the next 20 years we will see the present fleet of nuclear plants operate without incident.

Thank you very much, Madam Chairman.

[The prepared statement of Dr. Weinberg follows, and 100-page report follows:]

TESTIMONY ON THE U.S. NUCLEAR PROGRAM*

Alvin M. Weinberg
Institute for Energy Analysis
Oak Ridge Associated Universities
Oak Ridge, Tennessee 37830

I am grateful for the opportunity to appear before this subcommittee once again to express my views on the U.S. nuclear program. The Institute for Energy Analysis has recently completed a two-year study of the outlook for a Second Nuclear Era sponsored by the Andrew W. Mellon Foundation. I shall be borrowing heavily from the results of that work in this testimony. My remarks will cover the following topics:

A. The current problems of nuclear power.
B. Inherently safe reactors as a desirable nuclear option.
C. The long-term needs for regulatory and institutional reform in the nuclear industry.
D. Restructuring the breeder program.
E. Conclusions and recommendations.

A. The current problems of nuclear power

The First Nuclear Era has come to a halt in the United States--no new reactor has been ordered since 1978. Yet as this committee has so correctly observed, it is of the greatest importance that we correct whatever technological and institutional deficiencies that have led to the end of the First Era--so that we can base the Second Era on better technology and on better institutions.

A modern LWR, though extremely safe, is festooned with safety systems, all of them geared to keep the core cool even after the primary cooling has failed; and most of the auxiliary systems must spring into action in a matter of minutes. The original simplicity of the LWR--one of the features that recommended it for naval propulsion--has given way in its central station embodiment to a complicated array of controls, auxiliary cooling systems, redundant power supplies, and complex instrumentation. And the operating staff of a light water reactor may be thrust rapidly into a novel situation requiring prompt actions to avert damage to the plant.

---

*Presented before the Subcommittee on Energy Research and Production, U.S. House of Representatives Committee on Science and Technology, Washington, D.C., February 7, 1984.

All of this has contributed to the rising cost of LWRs. As uncertainties have developed regarding the integrity of the core under very unlikely, but possible, accident conditions, new requirements have been mandated by the NRC to deal with these contingencies. The multiplicity of these requirements has strained the resources of the utility owners of plants in operation or under construction. Some projects have been abandoned with nearly completed plants because the owners could not support the open-ended risk of being able to gain an operating license.

Reactors coming on line during the 1980s will cost between $1100 and $3500 or more per kilowatt (1983 $); this is to be compared to about $577 per kilowatt (also 1983 $) on the average for 57 reactors completed before 1981. Though some of the escalation is directly attributable to the added safety devices, most of the escalation comes from a combination of poor labor productivity, high interest rates and stretched-out construction schedules--the latter resulting either because demand has not risen as fast as had been anticipated or because of poor management. Were nuclear plants less complicated, their construction would place fewer demands on their designers and builders. Reactors at the low end of the cost range are still quite economical; those at the high end of the range are an embarrassment to the industry.

Ambivalent public attitudes toward nuclear power constitute another important barrier toward new plants. Many members of the public do not trust the nuclear industry or its regulators. The plants are regarded as unsafe and expensive. Nuclear wastes are considered an unsolved problem, even with the Nuclear Waste Policy Act of 1982.

It is all too easy to dwell on the deficiencies of light water reactors revealed during the First Nuclear Era. But the accomplishments as an economical source of power must be set against these deficiencies. Our analysis indicated that the present reactors are extremely safe and generally satisfy the NRC's proposed safety goals, and that new standardized LWRs are likely to be even safer. LWRs have produced and are producing substantial amounts of electricity (about $15 billion worth per year) reliably, with essentially no environmental impact, and with no known fatalities caused by radiation.

The following sections of this testimony emphasize new initiatives which I believe are vital for the long-term health of the nuclear option. In supporting such initiatives, we should keep in mind that the single most important action for preserving the nuclear option is the continued safe and efficient construction and operation of the present nuclear plants.

B. Inherently safe reactors as a desirable nuclear option.

I strongly support the letter of November 14, 1983 to the Secretary of Energy from Don Fuqua, Chairman of the Committee on Science and Technology and Marilyn Lloyd, Chairman of this subcommittee. That letter recommends that DOE fund development of inherently safe reactors.

An appraisal of inherently safe reactors was a major focus of the Second Nuclear Era study. By inherently safe we mean that safety depends not on the intervention of humans or of electromechanical devices, but instead depends on immutable and well-understood laws of physics and chemistry.

We were rather surprised, and not a little pleased, to discover two well-thought-out ideas for inherently safe reactors: the Process Inherent Ultimately Safe (PIUS) Reactor being developed in Sweden by ASEA-ATOM; and the modular High Temperature Gas Reactor, proposed by GA Technologies in this country, and by Interatom, a subsidiary of KWU in Germany.

In view of the Swedish moratorium on nuclear power, ASEA-ATOM decided in 1979 to go back to first principles and design a light water reactor that would be incontestably safe to operate. The PIUS concept consists of a pressurized water reactor submerged in a large pool of cold borated water. Their criteria included not only safety from the standpoint of any conceivable accidents caused by equipment or operator failures, but also safety from external events such as earthquakes and from sabotage or terrorist attack. This protection is gained without calling into action any active safety equipment and without any human actions. The intrinsic protection should last a week or more to provide time for preparation of further protective action. It is also desired to be able to operate the plant after such an outage. Many experts have examined this new concept critically and have been unable to find any series of events, including sabotage and terrorist actions, that appear to have an appreciable probability of causing severe damage to the reactor core. Thus the system is perhaps unique and deserves special attention.

Our preliminary appraisal of the PIUS reactor indicated that it had a reasonable chance of being economic. The PIUS reactor would presumably avoid the continual and expensive testing and replacement of safety system components characteristic of a conventional LWR. The main new cost item in PIUS is the massive concrete pressure vessel. Although such vessels have been built for large gas-cooled reactors in the United Kingdom and developed for water reactors in Sweden, the cost in a U.S. setting is uncertain. The amount of concrete and steel per kW of capacity in PIUS is expected to be in the same range as in some U.S. light water reactors. The cost of the vessel tends to be offset by elimination of the safety systems and redundant equipment no longer required.

The commercial application of PIUS would require a staged development program to prove its feasibility and to demonstrate its licensability and operability. Since PIUS is a modified PWR, much technology already in commercial use could be applied. However, even under favorable circumstances it would take 8 to 9 years to put a demonstration plant into operation, according to ASEA-ATOM. In view of the funding process for reactor development in the United States, we believe a realistic schedule for this country would be 12 years and a realistic budget about $500 million.

We believe there are reasonable possibilities for U.S. participation in a PIUS development program which might be pursued jointly with ASEA-ATOM, foreign governments, and the private sector. The first stage of such a program would not involve any commitment to a prototype but consist of investigations to prove the operability of the device, component studies to define important mechanical details, licensability investigations, and the development of a budgetary cost estimate.

The other inherently safe reactor concept, the modular HTGR, is also a promising candidate and we strongly support continuation and expansion of the existing R&D program. Again there are opportunities for cooperating in R&D with foreign governments and the private sector. We believe the critical challenge here to be the development and licensing of a design that can be marketed at a cost low enough to be attractive for base-load power production.

C. The long-term needs for regulatory and institutional reform in the nuclear industry.

Many utility executives have stated that they would never again buy a nuclear plant unless there were radical improvements in the licensing process. What they are seeking is predictability of schedule and cost for a nuclear project. Maintaining a viable nuclear option requires substantial improvement in the way our institutions function. Strengthening these institutions should be a continuing concern of your Committee.

Proposed legislation for licensing reform has been submitted to the Congress. In our view this legislation is desirable but it is not likely to be sufficient to make nuclear projects viable once again.

We believe there is a need to study more profound changes in the way licensing and regulation are carried out, and in the relationships between the nuclear industry and the regulators. The present maze of regulations needs to be simplified to focus on those few elements which really make a plant safe. New designs which provide a high degree of safety assurance should be licensable without having to satisfy each of the hundreds of overlapping NRC requirements which currently exist. In this way, the talent of both the industry and the regulators could be utilized more productively than at present.

The nuclear plant owner-operators need to become technically stronger and to exercise greater responsibility for the safety of their plants, as opposed to merely satisfying the regulations. The NRC could then assume an auditing and overview role, rather than the current role of dictating innumerable details. The existence of new industry standard-setting organizations such as the Institute of Nuclear Power Operations could facilitate such desirable institutional change.

We believe that improved technology can contribute to the evolution of a better institutional framework. As nuclear plants become safer, and particularly where safety depends on passive rather than active systems, their regulation should become easier and the overall viability of nuclear power should be enhanced.

D. Restructuring the breeder program.

The demise of the Clinch River Breeder Reactor requires a total restructuring of the U.S. breeder effort. I believe that a breeder option is a necessary element of the country's long-term energy strategy.

Present circumstances, where the United States no longer has its own prototype reactor, create a strong need for our collaboration with the foreign breeder programs.

The Second Nuclear Era study indicated very strongly that low capital costs and high inherent safety were very important characteristics for a breeder. Accordingly, we encourage you to support development in the United States of innovative breeder concepts which have such characteristics. Considering the present hiatus in the growth of nuclear power in the U.S., I would be inclined to place more emphasis on this type of breeder development than on the alternative of immediately designing a new

U.S. prototype to fill the gap created by the Clinch River Breeder Reactor cancellation.

E. Conclusions and recommendations.

1. Incrementally-improved, post-Three Mile Island, light water reactors pose very low risks to the public. However, investor risk and high and uncertain capital costs may limit their market in the United States.

2. Inherently safe reactors appear to be practicable. The development of such reactors should be undertaken to provide a technological alternative for widespread deployment in the future. If preliminary development of such systems continues to show promise, a prototype of such reactor(s) should be built to better define operability and economics, and to prove the safety characteristics.

3. Studies should be undertaken of long-term regulatory and institutional reform to allow the society to benefit from the improved nuclear technology which will be forthcoming.

4. The breeder program should be restructured to emphasize international cooperation and the U.S. development of innovative technology which will reduce breeder capital costs and increase inherent safety.

5. The above recommendations should not be pursued at the expense of reducing effort to make the present nuclear plants safe and economical. The success of the present plants is necessary to support a continuation of the nuclear option.

IS/AMW:bc
2-6-84

ORAU/IEA-84-6 (M)
Research Memorandum

THE SECOND NUCLEAR ERA

Alvin M. Weinberg
Irving Spiewak
Jack N. Barkenbus
Robert S. Livingston
Doan L. Phung

February 1984

Institute for Energy Analysis
Oak Ridge Associated Universities
Oak Ridge, Tennessee 37831-0117

Research memorandums document substantive work in progress and receive internal review.

This report was prepared under contract number DE-AC05-76OR00033 between the U.S. Department of Energy and Oak Ridge Associated Universities with funds provided by The Andrew W. Mellon Foundation.

CONTENTS

Page

List of Tables.. vii

List of Figures.. ix

Abstract.. xi

Executive Summary..xiii

CHAPTER I - INTRODUCTION.. 1

The Waning of the First Nuclear Era.. 4

The Criteria for a Second Nuclear Era.. 10

The Plan of this Report.. 15

CHAPTER II - TECHNICAL AND ECONOMIC ISSUES 19

Technical Paths to a Second Nuclear Era.. 19
- Pressurized Water Reactors (PWRs).. 19
  - The Sizewell B.. 19
  - The Combustion Engineering System 80 PWR.. 23
  - The Kraftwerke Union PWR.. 23
  - The Westinghouse Advanced PWR.. 24
  - The Westinghouse Two-Loop Reactor.. 25
  - The Consolidated Nuclear Steam Supply.. 26
- Boiling Water Reactors (BWRs).. 26
  - The BWR/6 Design.. 26
  - The Advanced BWR.. 29
- Heavy Water Reactors--The CANDU-Pressurized Heavy Water Reactor.. 29
- The High Temperature Gas-Cooled Reactor (HTGR).. 31
- Inherently Safe Reactors.. 35
  - The PIUS Reactor.. 35
    - Description.. 36
    - Control.. 36
    - Protection from Terrorist Attack.. 38
    - Crucial Problems.. 39
  - The Modular HTGR.. 40
  - Other Inherently Safe Concepts.. 43
    - The Horizontal BWR.. 43
    - The Deep-Well Reactor Concept.. 44
    - Inherently Safe LMFBRs.. 44
    - The Pool-Type Steam-Cooled Reactor.. 45
  - Selection of a Reference Inherently Safe Concept.. 45

CONTENTS (Continued)

Page

Technical Review of the Safety of Reactors........................ 46
  Safety Institutions and Philosophy........................ 46
  Operational Problems and Fixes........................ 48
  The Rasmussen Reactor Safety Study........................ 50
  The Accident at TMI and its Repercussions........................ 52
  The Nuclear Source Term........................ 57
  The Safety of Reactors Before and After TMI........................ 58
  Future Directions for Reactor Safety........................ 59

The Economics of Nuclear Power........................ 61
  Economics of Operating Nuclear Reactors........................ 61
  Economics of Nuclear Plants Under Construction........................ 65
  Trends Affecting the Economics of Nuclear Power........................ 68
  Prospects of Nuclear Power Economics in the Second Nuclear Era........................ 72

The Nuclear Fuel Cycle........................ 74
  The Assurance of Nuclear Fuel Supply........................ 74
  Nuclear Waste Management and Siting........................ 79

CHAPTER III - INSTITUTIONAL ISSUES FOR A SECOND NUCLEAR ERA....... 81

Licensing and Regulation........................ 81

Industry and Regulator........................ 82

Self-Regulation........................ 84

Possible Institutional Futures........................ 85

CHAPTER IV - SUMMARY, RECOMMENDATIONS, AND OBSERVATIONS........... 87

Summary of Findings........................ 87
  The Safety of Current Reactors........................ 87
  Are Current Reactors Safe Enough?........................ 88
  Comparison of Existing Reactor Types........................ 88
  Prospects for Inherently Safe Reactors........................ 89
  Costs........................ 90
  Reactor Regulation........................ 90
  Assurance of Fuel Supply, Waste Disposal, and Siting......... 91
    Assurance of Fuel Supply........................ 91
    Waste Disposal and Siting........................ 93

Recommendations........................ 95
  An Inherently Safe Prototype Reactor Should be Built......... 96

Plans for a Second Nuclear Era........................ 97
  Time Horizon........................ 98
  Leadership........................ 98
  Reactor Technology........................ 99

CONTENTS (Continued)

Page

Regulation.. 100
Siting.. 100
The Industry.. 100
Fuel Assurance.. 102

References.. 103

COMMENTS BY MEMBERS OF THE SECOND NUCLEAR ERA ADVISORY COMMITTEE.. 113

LIST OF TABLES

Page

Table 1. Increased Regulatory, Material, and Labor Requirements for U.S. Nuclear Plants.................................. 66

Table 2. Power Plant Capital Investment Costs Estimates for Commercial Operation in 1995........................... 69

LIST OF FIGURES

Page

Figure 1. Trends in Energy Usage.............................. 9

Figure 2. Reactor Vessel Internals of Large PWR Plant........... 20

Figure 3. BWR-6 Reactor Assembly.............................. 27

Figure 4. CANDU Reactor Assembly.............................. 30

Figure 5. 2240 MWt HTGR Nuclear Steam Supply System............. 33

Figure 6. PIUS Concrete Vessel and Primary Reactor System....... 37

Figure 7. Cross Section of a Modular Unit for Steam Generation.. 42

Figure 8. Trends in Average Costs of Coal and Nuclear Electricity in the United States...................... 62

Abstract

The Institute for Energy Analysis with support from the Andrew W. Mellon Foundation has studied the decline of the present nuclear era in the United States and the characteristics of a Second Nuclear Era which might be instrumental in restoring nuclear power to an appropriate place in the energy options of our country. The study has determined that reactors operating today are much safer than they were at the time of the TMI accident. A number of concepts for a supersafe reactor were reviewed and at least two were found that show considerable promise, the PIUS, a Swedish pressurized water design and a gas cooled modular design of German and U.S. origin. While new safer incrementally improved conventional reactors are under study by the nuclear industry, the complete lack of new orders in the United States will slow their introduction and they are likely to be more expensive than present designs. The study recommends that supersafe reactors be taken seriously and that federal and private funds both be used to design and if feasible to build a prototype reactor of substantial size.

EXECUTIVE SUMMARY

The accident at Three Mile Island has all but ended the first nuclear era in the United States. No new reactor has been ordered since 1978, and some 58 reactors either ordered or under construction have been cancelled. Nevertheless, the incentives to preserve the nuclear option remain very strong. Power delivered from nuclear plants continues to be cheaper than power from fossil plants. Nuclear power in many ways poses a lesser threat to the environment than does coal-fired power.

The Institute for Energy Analysis obtained support from The Andrew W. Mellon Foundation to investigate whether a Second Nuclear Era might be possible based on power reactors that are inherently more forgiving than current light water reactors. In order to gain a perspective on the potential of inherently safe reactors, it was necessary to assess also the current trends in safety of commercial reactors, and the economics of nuclear plants were evaluated since no technology could be deployed if it were not economic.

If we measure the safety of reactors by the median probability of a core melt as revealed by probabilistic risk assessment, then we must conclude that every one of the commercially available reactors—pressurized water reactor, boiling water reactor, heavy water reactor and high temperature gas-cooled reactor—is sufficiently safe; that is, its median core-melt probability is not higher than the proposed NRC safety goal, 10^{-4} per reactor-year. We found that the core-melt probability for LWRs is on average about three- to sixfold lower today than it was before Three Mile Island (TMI) because of voluntary and Nuclear Regulatory Commission-mandated changes carried out after TMI. In addition, estimates of the fission product release from most accidents have been reduced considerably from pre-TMI predictions.

Although present reactors are very safe, their safety depends on the proper response of active safety systems and plant operators during emergencies. The Process Inherent Ultimately Safe reactor proposed by ASEA/ATOM appears to be inherently safe--i.e., no sequence has been identified that would lead to a core melt. Moreover, PIUS seems to be highly resistant to acts of sabotage or war and to be particularly forgiving of inadvertency on the part of the operator. If PIUS could be built as cheaply as an LWR, and if it could be operated conveniently and reliably, then it could be a means for restoring confidence, as well as increasing utility interest, in nuclear power.

While PIUS is a unique concept, we expect that it is not the only possibility for an inherently safe reactor. Small, "modular" gas-cooled reactors have fail-safe characteristics and may be of interest in a Second Nuclear Era.

There will be no Second Nuclear Era unless the costs of nuclear power are kept under control. The cost of nuclear power from the plants currently in operation is low, provided average or better plant availability is achieved. By current standards, the initial investment in these plants was a bargain, and even if the order of $150 per kW has been spent on each unit for backfitting, the plants are still very competitive with fossil plants.

The plants currently under construction have expected costs varying from about $1100 per kW to $3500 per kW or more (in 1983 $). At the low end of the scale nuclear power is competitive with coal; at the high end of the scale nuclear power is unattractive.

Based on the above findings, our study has come to two main conclusions and recommendations:

1. That incrementally-improved, post-TMI light water reactors pose very low risks to the public even in a world with several times as many reactors as are now operating. However, investor risk and high, uncertain capital cost may limit their market.

2. The development of a Process Inherent Ultimately Safe (PIUS) reactor or other inherently safe concepts should be undertaken, to provide a technological alternative with intrinsic safety as an option for widespread deployment in the future. If preliminary development of the system continues to show promise, a prototype of such a reactor should be built to better determine its operability and economics and to prove its safety characteristics.

The development of even safer conventional reactors is already taking place with the commercial development of advanced pressurized and boiling water reactors. If the incrementally improved LWR is to be the only option available for a Second Nuclear Era, there may be little that government or the nuclear enterprise need do beyond what is now being done.

We are unconvinced that such a laissez-faire approach provides an adequate range of options or is an optimal course for extensive deployment of reactors in a world where there is much concern about the safety of nuclear plants.

We urge development of PIUS or an equivalent inherently safe concept to a stage where its practicality can be determined. This would require a prototype of about 100 MWe and would cost on the order of $500 million. Such an undertaking might be international, and we can envisage private sources providing some of the funds.

We are not unmindful that this recommendation could be interpreted to imply that we do not believe current reactors are safe enough. On the contrary, we are convinced that existing, post-TMI reactors pose low risks to the public. We believe, too, that evolutionary changes to LWRs could make them safer still. However, the evolutionary changes to LWRs have tended to improve safety at the expense of greater complexity and cost. We believe that a reactor that derives safety from simple features that are inherent in the system could profoundly increase the acceptability of nuclear energy.

CHAPTER I. INTRODUCTION

The first nuclear era ended in the United States with the accident at Three Mile Island on March 28, 1979. Actually no new reactor had been ordered since 1978*; and between 1978 and 1983, 58 reactors[1] that had been ordered or were under construction were cancelled. Other countries, notably Sweden, the Netherlands, and Austria have also turned away from nuclear energy, at least for the time being.

Nevertheless, the incentives to preserve the nuclear option remain very strong. Though the world today is experiencing an oil glut, this is surely a temporary phenomenon. Every economical alternative to oil ought therefore to be maintained: nuclear power is one of the most important of these alternatives. Power delivered from nuclear plants continues to be cheaper than power from fossil plants. Nuclear power in many ways poses a smaller threat to the environment than does coal-fired power. This became very evident in 1983 with the increased concern over acid rain. In the long run, with the accumulation of carbon dioxide and the depletion of fossil fuel, nuclear power will afford an economical alternative that would eliminate these concerns.

Today, 13 percent of the electricity[2] used in the United States is generated with light water reactors. When reactors under construction are completed, nuclear fission will provide about 20 percent of the total electricity[3] that will be used in 1990. The fleet of reactors will represent an investment of $150 billion (1983 $)--an extraordinary achievement for a technology that was totally unknown 50 years ago.

Few in the energy business would therefore dispute that preservation of the nuclear option is an extremely important element of national energy policy. This was a finding of the Institute for Energy Analysis 1976 study, "Economic and Environmental Implications of a U.S. Nuclear Moratorium 1985-2010."[4] In this study the Institute for Energy Analysis concluded that the United States could undergo a period of 25 years with no new nuclear reactors and not suffer intolerable environmental and economic consequences; however, the pressure on coal would become very great, and we therefore recommended that all necessary measures be taken to maintain the viability of nuclear energy.

---

*In 1975, the peak year, a total of 236 reactors were operating, under construction, on order, or announced in the United States. Since this time 92 of these reactors have been cancelled or discontinued. Of the remaining 144 reactors on the books, ten do not have current scheduled completion dates and it is possible that some of these may be abandoned in the future.

These sentiments echo those of David Lilienthal, the chairman of the Tennessee Valley Authority during World War II and the first chairman of the Atomic Energy Commission. In his book, Atomic Energy, A New Start,[5] written in 1980, Lilienthal argued that nuclear energy must not be allowed to die and that a key element in its resurrection was development of reactor systems that were regarded by the public as patently and transparently safe. Thus Lilienthal anticipated a rebirth of nuclear energy: a Second Nuclear Era based on better reactors and better institutions.

Lilienthal discussed his ideas with the staff of the Institute for Energy Analysis shortly before his death; we were pleased that many of his ideas were consistent with ideas for improving nuclear energy that the Institute had promulgated in the wake of its nuclear moratorium study. These ideas had been discussed at two Gatlinburg Workshops on "An Acceptable Future Nuclear Energy System"--the first held in 1976;[6] the second in 1979[7] after the TMI-2 incident--and at a third workshop on "Acceptable Nuclear Futures" at Oak Ridge in 1980.[8] Though the Gatlinburg workshops were concerned primarily with institutional improvements, the possibilities of better technology were never far from the minds of the participants. The 1980 workshop, attended by a dozen of the old-timers who had set the technological paths for the current nuclear era, recommended serious study of power reactors that were inherently more forgiving than current light water reactors. In 1981, IEA therefore requested support from the Andrew W. Mellon Foundation to investigate primarily technological approaches to the development of nuclear reactors that would fulfill the requirements set down by David Lilienthal--first and foremost, reactors that were sufficiently safe to restore the confidence in nuclear power which had been shattered by the TMI-2 accident. The Mellon Foundation has supported our project with two grants--one for $400,000 to investigate technological alternatives and a second of $53,000 to examine regulatory barriers to a rational nuclear energy system. In addition, the Institute has used a previous Mellon grant to support three senior fellows who spent several months at IEA working on our project. We are very grateful to the Mellon Foundation for this generous support.

Our study was conducted over a two-year period from October 1981 to September 1983 by staff of the Institute for Energy Analysis. Thirteen papers, by staff members and by outside organizations or consultants, were prepared. Two additional related papers were undertaken by IEA staff members for the Office of Technology Assessment. These supporting papers are referenced in this report as appropriate and several are being published as Research Memoranda. Workshops were held on reactor costs and on the safety of the Process Inherent Ultimately Safe (PIUS) reactor concept. We were helped very much by our Advisory Committee: Hans Bethe, David Freeman, John C. Franklin, Joseph Hendrie, and Herbert G. MacPherson. Our conclusions however, are not necessarily endorsed by the Advisory Committee. We therefore have invited each member of the Advisory Committee to comment on our findings. These comments are included at the end of the report.

In conducting our study, we invited the views of many of the Western world's reactor community. Our study therefore had the benefit of advice and consultation from Combustion Engineering, Commonwealth Edison, Electric Power Research Institute, General Atomic, General Electric, Institute of Nuclear Power Operations, Nuclear Regulatory Commission, Oak Ridge National Laboratory, Tennessee Valley Authority, and Westinghouse in the U.S.; the United Kingdom Central Electric Generating Board; Interatom and KWU in Germany; ASEA-ATOM in Sweden; and Hitachi in Japan. We are grateful to all of these organizations for their cooperation and help.

THE WANING OF THE FIRST NUCLEAR ERA

Nuclear power grew out of the military uses of fission--first as a by-product of the atom bomb and then as a spin-off from the pressurized water reactor developed originally to power the American nuclear navy. Of the world's 277 reactors[9] operating in 1983*, fully 212, representing 77 percent of all nuclear power, are light water reactors (LWRs), 129 are pressurized water reactors (PWRs) and 83 are boiling water reactors (BWRs). In the United States the light water reactor is used in all but three power-producing installations.

The light water reactor, a direct descendant of the submarine reactor, shares with the latter its inherent advantages and deficiencies. First of all, the LWR is simple in concept: light water--as moderator, coolant, and working fluid--has long been familiar to the utilities. Beyond this, the LWR is the most compact of the thermal neutron reactors. A large PWR operates at a volumetric power density of 100 kW per litre,[11] and its specific power averages about 40 watts per gram of fuel.[12] These two characteristics--inherent simplicity and compactness--were decisive in the original decision to base submarine propulsion on the light water reactor.

Because the LWR is so compact, its thermal inertia is small; perturbations of the system are reflected quickly in changes of temperature and pressure. If cooling were interrupted in a 1000 MWe PWR, the temperature of the water would increase at the rate of about 30°C per minute even after a scram. The temperature rise would be accompanied by a rapid increase in primary system pressure. Thus a primary design criterion for all PWRs requires that the core be cooled adequately after a loss of coolant accident during the short time available before an uncooled core would suffer serious damage.

---

*Worldwide there were 518 power reactors[10] operating or under construction in 1983. Of these, 277 are operating. Also, 415, or 80 percent of the reactors, are LWRs.

This requirement, which in good measure derives from the inherent compactness of the LWR, compromises the inherent simplicity of the system. A modern LWR is festooned with safety systems, all of them geared to keep the core cool even after the primary cooling has failed; most of these auxiliary systems must spring into action in a matter of minutes. The original simplicity of the LWR--one of the features that recommended it for naval propulsion--has given way in the LWR's central station embodiment to a complicated array of controls, auxiliary cooling systems, redundant power supplies, and complex instrumentation.

This has contributed to the rising capital cost of LWRs. Actually, it has not been so much the intrinsic cost of the individual safety systems that has raised the price of the LWR as it is the changing nature of the regulations requiring redesigns and rework. Because the measures to ensure the safety of the LWR are themselves complex, questions regarding their adequacy are more easily raised than answered. For example, the arduous hearings on the emergency core cooling system (ECCS) of 1972 stretched over 23 months and filled 22,000 pages of testimony.[13] The emergency core cooling systems designed at the time have since been proven to be more than adequate; nevertheless, the hearings led the regulatory branch of the Atomic Energy Commission (AEC) to mandate operating limits on LWRs that have added to the operating costs of the reactors.

One can give many other examples of how uncertainty as to the integrity of the core under very unlikely, but extreme, accident conditions has resulted in the mandating of new back-up systems or the reworking of existing systems. Perhaps the most prominent are the measures now required to earthquake-proof plants. The guarantee that an LWR can ride out an earthquake-induced acceleration of 0.25 g has required the addition, on average, of about $150 million worth of snubbers, pipe supports, and engineering.[14] The snubbers are unreliable and subject to frequent failure; the piping consequently may become overstressed during thermal cycling. The resulting pipe work is now very rigid: but by like token, access to equipment for inspection or repair is less convenient. Whether the attempts to improve resistance to earthquakes have improved safety remains arguable.

With growing operating experience, other difficulties with LWRs have revealed themselves--notably, pipe cracking in BWRs, steam generator failures in PWRs, and embrittlement of some of the early pressure vessels. Some of these deficiencies are traceable to the properties of the light water coolant, rather than to the low thermal inertia of the LWR. Though for each of these deficiences, fixes seem to be available, their presence tends to reduce the attractiveness of nuclear power based on light water reactors.

Reactors coming on-line during the 1980s will cost between $1100 and $3500 or more per kilowatt (1983 $),[15] compared to about $587 per kilowatt (1983 $) on the average for the 57 reactors[16] completed before 1981. Though some of the escalation is directly attributable to the added safety devices, most of the escalation comes from a combination of poor labor productivity, high interest rates, and stretched-out construction schedules--the latter resulting either because demand has not risen as fast as had been anticipated or because of poor management. If nuclear plants were less complicated, their construction would place fewer demands on their designers and builders. Insofar as safety is responsible for these complications and resulting management inadequacies, one can, at least indirectly, attribute to safety concern a large share of the cost over-runs experienced by some unfortunate nuclear projects.

Public attitudes toward nuclear power, reflected in an ambivalent Congress and sometimes hostile state and local governments, reflect the impact of Three Mile Island and cost over-runs. Polls show that less than half the public favors expansion of nuclear power.[17] The concerns most often cited are about reactor safety, cost, and nuclear waste disposal.

Nuclear reactors now being built often appear to their owners to be very expensive, complex and demanding, and beset with uncertainty. Based on a survey made by NRC in 1981,[18] it appears that the extensive changes mandated by the NRC following TMI were, in the eyes of the utilities, thrust upon the utilities with little or no planning and frequently required use of resources in an inefficient manner. The laudable goal of increase in plant safety and reliability was frequently lost in the demand of meeting unrealistic schedules with arbitrary priorities. A recent Electric Power Research Institute survey[19] of 11 utilities that operate light water reactors disclosed that the 57 utility management, operating, and maintenance personnel who were interviewed believed their reactors were safe but had reservations about a number of vital points closely related to safety and operability. These points are as follows:

> NRC-mandated additions of progressively more safety-related equipment too often reduce operability, maintainability, and availability; the rather uncoordinated superposition of so many systems may often reduce rather than increase safety.
>
> 1200-1300 MWe plants are too large.
>
> Containment buildings should be larger to provide more space for maintenance.
>
> Present plants respond too rapidly to transients.
>
> Nuclear plants should be less sensitive to events in secondary systems.
>
> The auxiliary feedwater systems need simplification and improvement.

The complexity of these plants creates risks to the investors. The risks are compounded by lack of public support. And with electricity demand currently growing at just over 2 percent per year[20] in the United States, instead of at the historical rate of 7 percent per year, the outlook for more nuclear power plants is doubtful.

We have gone full circle. One need only read the literature of the early 1950s to realize that at that time no one knew whether nuclear power would be cheap enough to compete with coal (then selling for $4 per ton), let alone natural gas at less than 10¢ per million Btu. In the 1962 AEC Report to the President on Civilian Nuclear Power[21] nuclear power was regarded as on the threshold of being competitive with conventional power only in the highest fuel cost areas. This period of doubt as to the economics of nuclear power was dispelled with the construction of the Oyster Creek 560 MWe boiling water reactor at a fixed price of about $348 per kWe and the H.B. Robinson pressurized water reactor at $265 per kWe (1983 $).[22] A tide of orders for reactors ensued, and by 1978, 202* reactors were either in operation, under construction, or on order.[23]

As the cost of nuclear reactors rose and demand for electricity fell below expectations, orders for new reactors diminished. Finally we reached the present moratorium characterized by no new orders and many cancellations.

It is all too easy to dwell on the deficiencies of light water reactors revealed during the First Nuclear Era. But the accomplishments as an economical source of power must be set against these deficiencies. As we stated earlier, 13 percent of the electricity in the United States is generated with light water reactors. In 1982, nuclear power was on the average 11 percent less costly than power from coal[24] in the United States. The economic advantages of nuclear power are even greater in Europe and Japan. LWRs have produced and are producing substantial amounts of electricity reliably, with essentially no environmental impact, and with no known fatalities caused by radiation, assuming that the waste disposal problem will eventually be solved.

During the past decade demand for primary energy in the U.S. has fluctuated between 79 quads and 71 quads per year.[25] The average demand for the decade was 75 quads. These fluctuations are shown in Figure 1. At the same time, the fraction of energy used in the form of electricity has increased as a percent of energy demand. In 1973 the fraction was 26.6 percent, and by 1982 it had increased to 34.1 percent. Also at the same time, the absolute generation of electricity increased from 1.86 trillion kWh to 2.24 tkWh, an average annual increase of just over 2 percent.[26] This trend toward electrification has been scrutinized at IEA; we

---

*In the peak year 1975, 236 reactors were operating, under construction, on order, or announced in the United States.

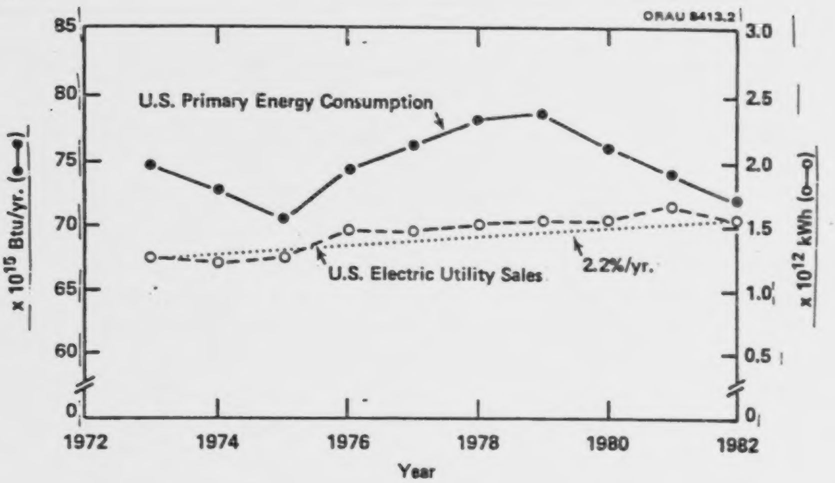


FIGURE 1. TRENDS IN ENERGY USAGE

Source: Energy Information Administration, Monthly Energy Review, DOE/EIA-0035 (83/06), June 1983, p. 80.

believe that it is likely to continue mainly because electricity is so important a factor in economic productivity. Basing the future growth of electricity production entirely on fossil fuels could introduce serious supply and environmental problems. Thus to deny a future in which nuclear energy provides an important fraction of the growing demand for electricity seems to us to be extremely imprudent. In short, as we concluded at the three workshops on nuclear power, let's fix nuclear energy, not bury it.

THE CRITERIA FOR A SECOND NUCLEAR ERA

As judged by the cancellation of many nuclear plants and the lack of new orders, utility investors and executives must regard further expansion of nuclear capacity as undesirable. Though some consider nuclear reactors to be too expensive, the main concern centers about the uncertainties that surround nuclear projects: Will the Nuclear Regulatory Commission require additional backfits? How long will construction last? Will the utility be able to attract and retain the necessary specialized talent? Given the very long lead time and the uncertain projections of growth in demand, will a nuclear plant become a white elephant? Will public utility commissions honor cost over-runs associated with nuclear plants? How large is the risk and how large the price of a repetition of TMI-2, even though TMI-2 caused no physical harm? What risks are introduced through potential public opposition to a nuclear project?

A Second Nuclear Era in the United States has as a prerequisite a recognition of need for additional generating capacity. No utility executive is likely to enter into new commitments for large blocks of capacity without strong increasing electrical demand and support from state agencies. One early signal of such an increase in demand would be a need for reactivation of some of the suspended nuclear projects, currently numbering ten.[27]

For nuclear energy to play its full role in the future, both a skeptical utility industry and a skeptical public must regain confidence in nuclear power. Some actions, such as demonstration of secure disposal of wastes, all agree must be taken. Fortunately, the passage of the Nuclear Waste Policy Act of 1982[28] at long last has set the stage for resolution of the waste issue. This Act levies a tax of 1 mill per kWh on all users of nuclear electricity, the tax to be used for waste disposal. By 1990 this should bring in close to $600 million per year.[29] Though one cannot expect that wastes will be handled in a fully acceptable way by then, one can at least say that the matter is now receiving considerable support and attention.

The unfavorable trends in nuclear plant costs must be reversed for nuclear power to regain favor in the marketplace. What magic did we possess in the late 1960s and early 1970s that allowed us to build plants that were cheap and are still regarded as adequately safe? Why does the industry not consistently run plants at a 65 percent or a 70 percent capacity factor instead of 55 percent? Still, one must realize that many of the reactors soon to go into operation are good economic bets. The alleged poor economics of nuclear plants is not based on the performance of the most successful plants but on the performance of the poorest. But for the utility executive who must decide whether to build or not, this gives little comfort: How does he know that his new plant will be among the best, not the worst?

Some of the uncertainty would be removed were the regulation of nuclear power both more flexible and more reasoned. For example, when a deficiency is discovered in a particular plant, all existing plants are usually required to backfit to remedy the deficiency. In some cases, as in the requirement for an unequivocal measurement of the water level in a PWR, such backfitting seems entirely reasonable. On the other hand, where a backfit simply assures conformance with an existing regulation, which is itself quite arbitrary, such action can be regarded as overly rigid. For example, was the NRC justified in requiring extensive reinforcement of vessel supports to prevent vessel motion in response to a highly improbable large pipe break at a particular location?[32] Or when TMI-1 was ordered to remain closed for years when other reactors of the TMI-2 type were allowed to operate, was this action motivated by a clear notion of what was thereby accomplished, or was it a rather capricious action prompted by the public and political upheaval caused by TMI-2? One would hope that a reborn nuclear energy industry could enjoy a regulatory system that is less subject to arbitrary decisions.

The central questions addressed by the Second Nuclear Era study are If future reactors are intrinsically safer than today's LWRs, would the nuclear industry be better off? And do plausible concepts exist for such forgiving reactors, either based on improved LWRs or on totally different combinations of coolant and moderator? In focusing on these questions, we make an underlying assumption: The frustrations over regulation, the mounting costs of reactors, and the public's disaffection with nuclear power are, in final analysis, traceable to concern over the 15 billion curies of radioactivity contained in a 1000 megawatt LWR. The radioactivity can never be avoided. But if one could design a device that would make a TMI-2-like incident essentially impossible, would not much of the current regulatory system be superfluous; would not the public's aversion to nuclear energy be reduced; and insofar as such concerns ultimately are reflected in high cost and risk, would not utilities once more regain their interest in nuclear power?

When IEA undertook this study, we realized that incremental improvements in LWRs afforded a path to safer reactors; and so much of our study has been devoted to assessing how safe LWRs have become because of post-TMI backfits. The improvements in LWRs have been impressive—so impressive, we believe that nuclear power, as compared with other risks, is very safe. We realize that such a judgment, made by a group who have long been tied to the nuclear enterprise, might appear biased. Moreover, we must also concede we adopted the stance that certain threats—acts of war, earthquakes beyond a certain size, sabotage, acts of terrorism—are too far-fetched to be considered in design standards. Yet, unlikely though they might be, one cannot give a totally compelling reason for ruling such events to be irrelevant: a Second Nuclear Era might last for a long time; events that on a short time scale may be regarded as too unlikely to occur, on a scale of hundreds of years, might be worthy of attention.

In the shorter run, it would make sense to have a totally forgiving reactor that is resistant to these very unlikely threats. Not all operators of nuclear power plants are equally competent. Utilities in countries with weaker technological tradition could not be expected to bring resources to their nuclear operations as strong as those of utilities in countries that have a strong technological tradition. Thus reactors that make fewer demands on the competence of their operators, constructors, and regulators would make nuclear power available in many more settings than is now practicable.

Fossil-fueled power plants are used in every country and by every utility; nuclear power plants are largely confined to those countries and to those utilities that have reached a high level of technological sophistication. That the technologically weaker countries may be prone to political instability strengthens the case for a reactor so forgiving that it could survive essentially any level of violence short of an attack with nuclear bombs.

We therefore have focused part of our study on a search for reactors that are intrinsically more forgiving than is the LWR--that is, reactors that depend for their safety, not on the intervention of safety devices, but rather on physical principles. We studied several such concepts, notably the ASEA-ATOM Process Inherent Ultimately Safe Reactor (PIUS)[30] and the small, modular high-temperature gas reactor.[31,32] We also reviewed, very briefly, a few other ideas, some of them very old, for inherently safe reactors. In all instances, inherent safety was achieved by providing the reactors both with much more thermal capacity than LWRs possess and/or a means for rendering a gross loss of core-cooling impossible.

In addition, we examined other types of commercial reactors--notably the high-temperature gas reactor (HTGR) and the Canadian deuterium uranium reactor (CANDU). We are grateful both to GA Technologies for its paper on HTGR safety[33], and to Atomic Energy of Canada Limited and Ernest Siddall for a paper on CANDU safety.[34]

Can a reactor be both intrinsically safe and affordable? Unless a forgiving reactor is affordable, no one will buy it. Of course, the balance between safe as possible and cheap as possible cannot be drawn once and for all, and for every country. Sweden, which has mandated a phase-out of nuclear power by 2010 and which has no indigenous fossil fuel, might be prepared to pay more for a very safe reactor than would the United States with its abundant coal. Nevertheless, we recognize the cost of a potentially forgiving reactor as being primary. We would contribute little to resolving the nuclear dilemma were we to recommend reactors that are too expensive, no matter how safe they are. Economic criteria must be met in the Second Nuclear Era just as they had to be met in the First Nuclear Era. Unfortunately, the ultra-safe reactors we have examined are mostly concepts, not realities. Whether they would be competitive, therefore, will remain uncertain until more work has gone into their design.

Another requirement for a Second Nuclear Era is more consistent and understandable regulation. Nevertheless, we are unconvinced that regulatory inadequacy per se is the central difficulty. In a democracy, a technology that is viewed as dangerous by half the public simply cannot be regulated in a way that all participants will consider fair and responsible. This situation will change only if the technology, as perceived by the public, is regarded as no longer threatening. We cannot say how much the technology must improve to accomplish this change in public attitude; safe and reliable operation during the next decade should be crucial. Improvements in the technology—either incremental (including standardization) or drastic—ought to convince all but the most doctrinaire that nuclear energy can be an acceptable source of energy.

Such technological improvements will avail us little in the Second Nuclear Era if the regulatory agency takes no heed of them. Intrinsically safe reactors would not require the regulatory scrutiny nor the prescriptive style that is now the rule. But whether the existing regulatory apparatus will accommodate itself to such technological improvements remains to be seen.

Other institutional reforms have been subjects of study at IEA during our Acceptable Nuclear Future project;[35,36] they remain relevant for the Second Nuclear Era. For example, we continue to find merit in a concentrated siting policy with most new reactors being added to existing sites: the ultimate configuration might then resemble that of the Canadian, French, Soviet, or Japanese, with as many as 8 reactors on each of 100 sites, most being expansions of existing sites. Consolidation of utilities and companies engaged in operating and constructing nuclear reactors appears to us to be inevitable. Eventually in the United States one might contemplate twenty such companies rather than the 60-odd utilities now so engaged. Measures such as this are ultimately aimed at increasing the flow of information within the nuclear community, so that never again need a TMI-2 happen without the operators knowing that very similar precursors had occurred at Oconee, Rancho Seco, and Davis Besse. But we do not pretend in this study to have done justice to all these institutional issues; nor have we examined in full detail waste disposal and fuel assurance, issues that will surely require resolution in a Second Nuclear Era. Our task was to examine possible technologies for a rebirth of nuclear energy based on forgiving reactors.

PLAN OF THIS REPORT

This report of the Second Nuclear Era study is divided into four chapters. Chapter I has summarized what went wrong with the First Nuclear Era and given the criteria for a Second Nuclear Era. Chapter II is a discussion of the technical issues, including a summary of the available reactor technology, a review of reactor safety, a summary of reactor economics, and a discussion of the nuclear fuel cycle. Chapter III is a discussion of the institutional issues. Finally, Chapter IV is a summary of the results of the study, presenting the conclusions and recommendations. There is an addendum giving comments by members of the Advisory Committee.

The main body of the report is augmented by a series of supporting papers presenting the studies on which many of our findings are based. Readers who wish to go more deeply into the technical justifications for our conclusions would do well to study these papers, lengthy though they may be. The following is a list of the supporting papers:

Technology of Reactors

K. Hannerz. 1983. Toward Intrinsically Safe Light Water Reactors. Research Memorandum, ORAU/IEA-83-2(M)-Rev. Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities. 105 pp.

A.J. Goodjohn, C. Fisher, P. Fortescue, A.J. Goodjohn, B.E. Olsen, and F.A. Silady, 1983. The HTGR—An Assessment of Safety and Investment Risk, GA-C16928. To be published as a Research Memorandum. Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities. 101 pp.

E. Siddall. 1983. The CANDU-PHW Reactor in Relation to a Second Nuclear Era, Research Memorandum, ORAU/IEA-83-11(M). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities. 21 pp.

A.P. Fraas. 1982. Survey and Assessment of the Technological Options Available to the Nuclear Industry in the 1980 to 2000 Period. To be published as a Working Paper. Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities, 40 pp.

Economics, Safety and other Technical Issues

D.L. Phung. 1983. Review of Light Water Reactor Safety Through the Three Mile Island Accident. Research Memorandum, ORAU/IEA-84-3(M), Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities, 114 pp.

D.L. Phung. 1983. Assessment of Light Water Reactor Safety Since the Three Mile Island Accident, Research Memorandum, ORAU/IEA-84-2(M). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities, 193 pp.

A. Weinberg. Waste Management in the Second Nuclear Era. To be published as a Working Paper. Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities, 12 pp.

D. Phung. 1983. Economics of Nuclear Power: Past Record, Present Trends, and Future Prospects, Research Memorandum, ORAU/IEA-83-13(M). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities, 36 pp.

I. Spiewak. 1983. An Investigation of the Nuclear Source Term. To be published as a Research Memorandum. ORAU/IEA-84-5(M). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities, 23 pp.

I. Spiewak. 1984. Option for the Assurance of Nuclear Fuel Supply. To be published as a Research Memorandum, ORAU/IEA-84-4(M). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities, 16 pp.

Institutional Issues

J. Barkenbus. 1983. Prospects and Opportunities for Nuclear Power Regulatory Reform. To be published as a Research Memorandum, ORAU/IEA-83-5(M). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities, 75 pp.

J. Barkenbus. 1983. An Assessment of Institutional Alternatives for Nuclear Power. To be published as a Working Paper. Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities, 49 pp.

I. Tiren. 1983. Safety Considerations for Light Water Reactor Nuclear Power Plants: A Swedish Perspective. Research Memorandum, ORAU/IEA-83-7(M). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities, 42 pp.

E. Siddall. 1983. The Future of the Nuclear Energy Industry (Thoughts on Alvin Weinberg's "Second Nuclear Era"). To be published as a Working Paper. Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities. 11 pp.

E. Epler. 1983. Optimization of Prevention Vs. Mitigation for Minimum Risk. To be published as a Working Paper. Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities. 35 pp.

CHAPTER II: TECHNICAL ISSUES

TECHNICAL PATHS TO A SECOND NUCLEAR ERA

Present-day light water reactors, evolutionary improvements to those reactors, high temperature gas-cooled reactors and heavy water reactors, as well as inherently safe reactors are all possibilities for use in the Second Nuclear Era. This section describes the technical characteristics of these devices.

As we have indicated in Chapter I, the most important criteria for choice of reactors in a Second Nuclear Era are safety and low cost. Other criteria are commercial availability, ease of licensing, and operability, though the latter is extremely difficult to assess.

Pressurized Water Reactors (PWRs)

A large number of pressurized water reactor designs have been built or proposed. Large "conventional" PWRs are currently offered by Westinghouse and Combustion Engineering in the United States, by Framatome in France, by Kraftwerke Union in Germany, by Mitsubishi in Japan, and by the Soviet Union. We cannot cover all of these designs and shall limit our discussion to a few that illustrate trends. These are the Westinghouse Sizewell B design, the Combustion Engineering System 80, the Kraftwerke Union PWR, the Westinghouse Advanced PWR, the Westinghouse Two-Loop Plant, and the Consolidated Nuclear Steam Supply of Babcock and Wilcox.

The Sizewell B Reactor

In the early 1970s, Westinghouse, together with a group of U.S. utilities and Bechtel, evolved a standard PWR design, SNUPPS.* SNUPPS is a conventional Westinghouse 4-loop reactor with vertical U-tube steam generators and is typical of today's U.S. plants (Figure 2).[37] The first plant

---

*SNUPPS: Standardized Nuclear Unit Power Plant System

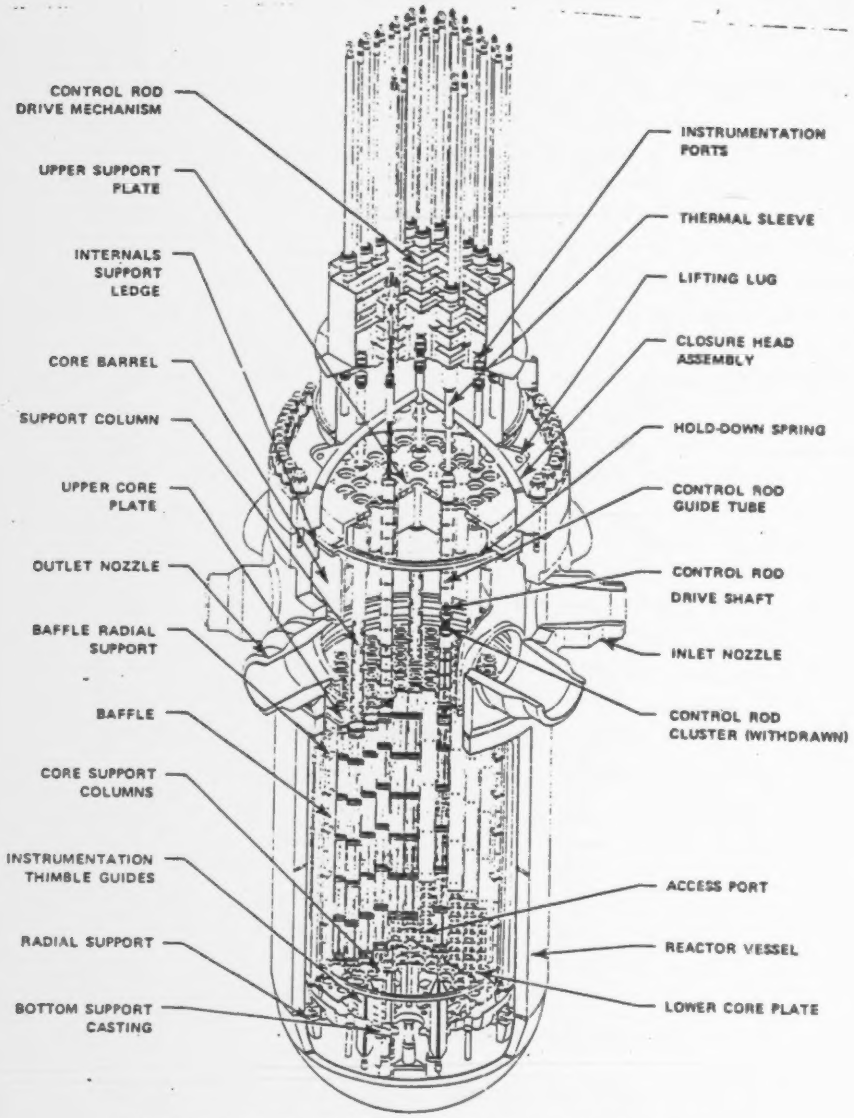

CONTROL ROD DRIVE MECHANISM
UPPER SUPPORT PLATE
INTERNALS SUPPORT LEDGE
CORE BARREL
SUPPORT COLUMN
UPPER CORE PLATE
OUTLET NOZZLE
BAFFLE RADIAL SUPPORT
BAFFLE
CORE SUPPORT COLUMNS
INSTRUMENTATION THIMBLE GUIDES
RADIAL SUPPORT
BOTTOM SUPPORT CASTING
INSTRUMENTATION PORTS
THERMAL SLEEVE
LIFTING LUG
CLOSURE HEAD ASSEMBLY
HOLD-DOWN SPRING
CONTROL ROD GUIDE TUBE
CONTROL ROD DRIVE SHAFT
INLET NOZZLE
CONTROL ROD CLUSTER (WITHDRAWN)
ACCESS PORT
REACTOR VESSEL
LOWER CORE PLATE

FIGURE 2. REACTOR VESSEL INTERNALS OF LARGE PWR PLANT

Source: Systems Summary of a Westinghouse Pressurized Water Reactor Nuclear Power Plant, Westinghouse Electric Corporation, 1971, p. 40.

of this series is Callaway, scheduled for operation in 1984. Unfortunately, the other SNUPPS plants have been cancelled.

SNUPPS incorporates two independent reactor shutdown systems with a backup emergency boration system, two high-pressure and two intermediate-pressure emergency core cooling pumps, and three diverse auxiliary feedwater supply systems to help remove residual heat from the steam generators. Most of these features are present in other Westinghouse LWRs, and SNUPPS may be regarded as being typical of modern Westinghouse PWRs. The core-melt probability of these plants as calculated by Probabilistic Risk Assessment (PRA) is usually in the range 10^{-4} to 10^{-5} per reactor year.[38]

An improved version of the SNUPPS design, and one in which the greatest attention has been given to safety, was prepared by and for the Central Electricity Generating Board (CEGB) in the United Kingdom for a plant designated Sizewell B. To meet the stringent requirements posed by the high population density in the vicinity of the site, the CEGB made an intensive 5-year study[39,40] of the reactor safety problems and the measures that might be taken to minimize the probability of an accident. This study was exceptionally thorough and included the exploration of a wide range of possibilities and much new design work.

The Sizewell B design[41] has increased safety above that of the SNUPPS (Callaway) design with the following additions:

1. Four high-pressure safety injection (HPSI) pumps dedicated to safety, each with heads lower than 2000 psi and with higher flow volumes than Callaway's. The actuation of the HPSI pumps will automatically shut down the higher head charging pumps, thus preventing overpressurization in overcooling transients.

2. Four accumulators, any two of which are sufficient for core cooling at the 600 psi pressure range (instead of the required three at Callaway).

3. Four low-pressure pumps to recirculate water for core cooling at low pressures and for the containment sprays. These pumps are dedicated to residual heat removal. In addition, the high pressure HPSI suction is automatically switched to the containment sump when the refueling water storage tank is low. In older Westinghouse reactors, including SNUPPS, such switching to this back-up source of water must be done manually.

4. An additional steam-driven auxiliary feed pump, in addition to the two electric pumps already in SNUPPS. All the pumps are farther apart than at Callaway and are therefore less subject to common-mode failure.

5. Four diesel generators (instead of two) to provide emergency power in the case of loss of offsite power.

6. Microprocessor-based reactor protection system backed up by a secondary protection system based on solid state switches.

7. Emergency boration system as a backup reactor trip system to cope with anticipated transients without scram.

8. Extra diesel-driven emergency charging pump to make up for pump seal leakage during station blackout.

9. An additional isolation valve between the high pressure reactor cooling system and the low pressure residual heat removal system to minimize the chance of the containment bypass accident sequence (the so-called V sequence).

10. Connections to provide water from fire pumps to containment safety features.

11. The reactor pressure vessel is constructed of ring forgings with no major welds in the beltline region of the vessel to minimize the chance of vessel brittle failure due to irradiation and overcooling transients.

12. A secondary containment vessel to further reduce the probability of an escape of radioactive material to the environment.

The probabilistic risk assessment for the Sizewell B reactor gives a mean core-melt probability of 1.1×10^{-6} per reactor year,[42] about 2 orders of magnitude below that of a typical U.S. reactor. The probability of a large release of radioactivity is estimated to be 3×10^{-8} per reactor year.[43] The cumulative impact of the measures designed to improve safety beyond that of the standard SNUPPS design has been estimated to increase the power plant capital cost about 20 percent.

The Combustion Engineering System 80 PWR

Combustion Engineering supplies a standard reactor with vertical U-tube steam generators, functionally equivalent to the standard Westinghouse system.[44] Their design uses 4 pumps and 2 steam generators. The first System 80 plants expected to become operational are the Palo Verde reactors. The System 80 protective instrumentation includes computers that monitor safety-related parameters in four parallel channels to prevent spurious trips and to retain high plant availability. The control rod design provides a large amount of control to maintain subcriticality at low temperatures without the presence of soluble boron. The System 80 primary system pressure is maintained without using pilot-operated relief valves which have been a source of operational problems at some PWR plants (including Three Mile Island-2).

The Kraftwerke Union PWR

Kraftwerke Union (KWU) in Germany has followed design practices somewhat different from those in the United States in developing their line of PWRs. These differences stem in part from the greater population density in Germany producing an even greater desire for engineered safety features. KWU employs both a lower power density and a lower heat flux in the reactor core than in the U.S. PWRs[45] (93 kW per liter versus 102 kW per liter and 48 W per cm^2 versus 68 W per cm^2, respectively). The KWU containment is backed by a secondary containment, and the containment vessels are larger, making it possible to separate equipment and hence reduce the chance of common mode failure. The reactor pressure vessels are made larger to reduce the fast neutron dose to the steel (by a factor of about 3 to 5), and the vessels are made of forged rings to eliminate axial welds at the reactor beltline region where radiation fluence is high. In addition, there is more separation of functions in the auxiliary systems and more capacity of the components. There are four independent primary reactor cooling circuits, for example, each with its own circulating pump and steam generator and each equipped with sufficient capacity in the pumps and tanks of its emergency feedwater system to remove at least half of the afterheat under emergency conditions. This equipment, together with a dedicated set of diesel generators to provide emergency power, is housed in a special shielded building. Both this building and the main reactor containment structure are designed to withstand the impact of an aircraft crash directly on the buildings. These buildings are also designed to withstand both severe earthquakes and attempted sabotage.

Throughout the plant there is extensive use of both redundancy and diversity in the instrumentation, controls, and auxiliaries. These measures are coupled with much physical separation to minimize further the possibilities and/or effects of common mode failures. (German regulations require greater protection against common mode failures than do those in the U.S.) These features, coupled with the measures outlined above, have led to a core melt probability, as estimated by PRA, of 10^{-5} per reactor year[46] for accidents that might cause serious core damage.

Studies[47] at Karlsruhe and KWU indicate that the probability of activity release from the containment system in the event of severe core damage is very low--of the order of 10^{-4}. Their analyses indicate that at least five days would be required for the pressure in the containment vessel to build up to the point where cracks would develop and leakage could start. Further, in the event of such a release, the amount of activity that would escape would be attenuated by factors of as much as 10^6[48] because iodine and cesium would remain dissolved in water and aerosols would largely settle or plate out.

The Westinghouse Advanced PWR

The Advanced PWR (APWR)[49] is a joint effort of Westinghouse and Mitsubishi Heavy Industries, intended initially for the Japanese market. It represents a further evolution of the Westinghouse four-loop design toward rather ambitious objectives: 90 percent plant availability, 20 percent savings in fuel cost, resistance to an 0.7 g earthquake, reduced public and occupational risk, load following capability, and capital cost at conventional levels.

Fuel utilization in APWR is improved by means of movable zirconia rods that displace water moderator and thereby adjust the neutron spectrum.

The safety system includes four high-pressure pumps, four accumulators (actuated at 600 psi), four core reflood tanks, four low pressure pumps, four heat removal exchangers, two emergency letdown heat exchangers, two refueling water storage tanks, two spray additive tanks, and one emergency water storage tank. Safety systems are separated more widely than in earlier Westinghouse designs. The secondary side of the steam generators can be equipped with four dedicated, passive, condensers and water storage tanks which enable the plant both to withstand a complete load rejection without actuating the primary relief valve, and to provide decay heat removal through the steam generators. The APWR containment is dry but has sumps normally filled with water to increase the heat absorption capacity and to ensure supply of water to the emergency pumps. The core-melt probability of the APWR is about 10^{-6} per reactor-year.[50]

The Westinghouse Two-Loop Reactor

Westinghouse offers a two-loop, 640 MWe PWR based on the design of a reactor[51] being built in the Philippines. The scope of supply is broader than the nuclear steam supply system and includes key safety-related items usually considered "balance of plant." The two-loop plants have operated much more reliably worldwide than the larger plants and are claimed by the vendor to be as economical as the larger plants.[52] They may appeal to utilities experiencing slow load growth or those who believe that 1200-1300 MWe plants are too large, as stated in the EPRI utility survey.[53]

The Consolidated Nuclear Steam Supply

The Consolidated Nuclear Steam Supply (CNSS) is a conceptual design for a 400 MWe PWR[54] developed by the Babcock & Wilcox Company and United Engineers & Constructors, Inc. The study was undertaken because of the anticipated advantages provided by a small, modular, standardized nuclear system: shorter lead time, greater certainty of capital costs, lower financial risk, maximum amount of shop fabrication, and simple safety features. The CNSS is an integral PWR with steam generators within the reactor vessel and pumps located vertically in the vessel head. The designers consider this type of design to be particularly economical for a period of low and uncertain electrical load growth.

Boiling Water Reactors (BWRs)

The two main suppliers of BWRs worldwide are the General Electric Company (GE) and ASEA-ATOM of Sweden. Hitachi and Toshiba supply BWRs in Japan, and KWU, in Germany. Boiling water reactors are supplied competitively with pressurized water reactors over roughly the same size range. They are illustrated by the BWR/6 and the Advanced BWR.

The BWR/6 Design

The BWR/6 is the current GE reactor system (Figure 3).[55] It is a direct cycle boiling water reactor with a reference Mark III pressure suppression containment. Steam is generated in the core and conveyed directly to the turbine.

A principal design feature of BWRs is the existence of a natural circulation flow path within the reactor vessel so that there is adequate coolant flow capacity for removing the afterheat from the core by natural thermal convection as long as the water inventory in the reactor vessel is maintained at the proper level. Further, the BWR primary system can be

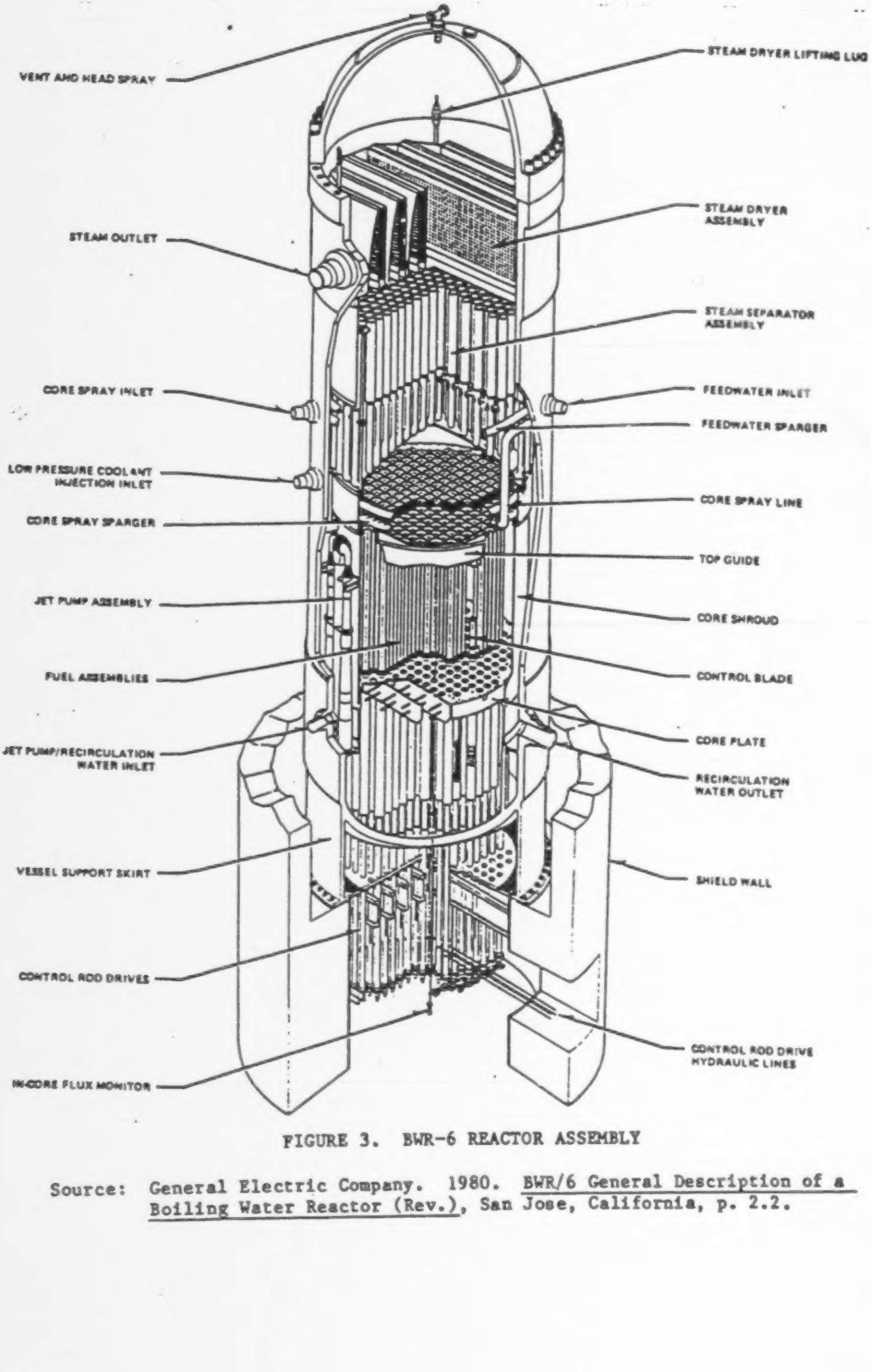

VENT AND HEAD SPRAY
STEAM DRYER LIFTING LUG
STEAM DRYER ASSEMBLY
STEAM OUTLET
STEAM SEPARATOR ASSEMBLY
CORE SPRAY INLET
FEEDWATER INLET
FEEDWATER SPARGER
LOW PRESSURE COOLANT INJECTION INLET
CORE SPRAY LINE
CORE SPRAY SPARGER
TOP GUIDE
JET PUMP ASSEMBLY
CORE SHROUD
CONTROL BLADE
FUEL ASSEMBLIES
CORE PLATE
JET PUMP/RECIRCULATION WATER INLET
RECIRCULATION WATER OUTLET
VESSEL SUPPORT SKIRT
SHIELD WALL
CONTROL ROD DRIVES
CONTROL ROD DRIVE HYDRAULIC LINES
IN-CORE FLUX MONITOR

FIGURE 3. BWR-6 REACTOR ASSEMBLY

Source: General Electric Company. 1980. _BWR/6 General Description of a Boiling Water Reactor (Rev.)_, San Jose, California, p. 2.2.

depressurized rapidly; low-pressure as well as high-pressure pumps can therefore be employed to maintain the proper water level in the reactor vessel. There are a total of 13 pumps in the BWR/6, 11 of which can individually handle nonbreak transients.

Other improvements include increased redundancy and separation of functions. These changes have resulted in a marked reduction in the probability of core melt for an accident that could result in severe damage to the core.

The Mark III containment is the latest version of the pressure suppression containments used on all but the very earliest BWRs. Pressure suppression containment systems employ a large pool of water (the suppression pool) and a system of vents leading from the reactor cavity to the suppression pool. Following a postulated reactor primary system rupture, steam and fission products released from the reactor will be channeled to the suppression pool. Experiments show that the bubbling of these materials through the pool should remove over 99 percent of the iodine and particulate fission products from the vented gases. Thus the vast majority of the radioactive fission products that might escape from the core in the event that severe core damage did occur would be retained within the primary containment system. The Mark III containment building has been enlarged and strengthened relative to earlier designs, and potential bypassing of the suppression pool has been eliminated.

From all this, it follows that not only is the probability of an accident that would cause severe damage to the core very low (about 5×10^{-6} per reactor year claimed by General Electric for the BWR/6[56] versus about 3×10^{-5} for the Peach Bottom 2 plant, an earlier BWR), but if such an accident were to occur, the probability of the escape of substantial quantities of fission products to the atmosphere would be exceedingly low.

The Advanced BWR

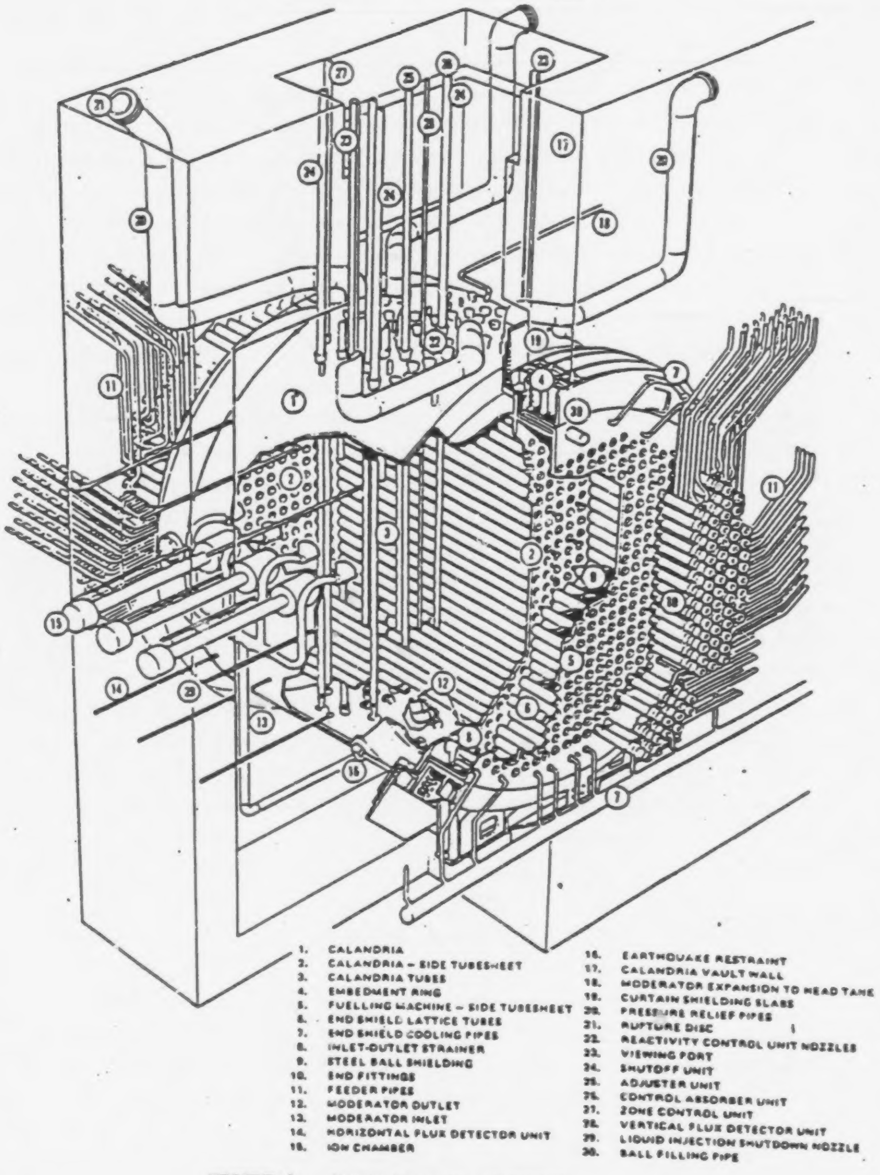
The Advanced BWR (ABWR)[57] is being developed for use in Japan by GE in partnership with Hitachi and Toshiba. The key feature of the ABWR is the use of in-vessel pumps for recirculation flow, a design that has been used successfully by ASEA-ATOM and KWU. The troublesome external recirculating piping can be eliminated, considerably reducing the size of the maximum pipe rupture which can occur. Another feature is the use of redundant electric and hydraulic fine motion control rod drives. Steam bypass capacity has been increased from 35 percent in the BWR/6 to 100 percent, thereby improving the ability of the BWR to respond to turbine trips. The design emphasizes increased redundancy, diversity and physical separation of systems, and multiplexing of the instrumentation.

The ABWR is expected to be more operable and safer than the already very safe BWR/6. Reduced exposure for the plant operators during maintenance is also expected.

Heavy Water Reactors--the CANDU-Pressurized Heavy Water Reactor

The CANDU reactor has been operated successfully by Ontario Hydro since 1968, when the 206 MWe Douglas Point reactor started. The four-unit Pickering station (515 MWe per unit) that started up in 1971[58,59] has been at or close to the top of the list of the world's reactors when ranked according to plant availability. A total of 16 CANDU-type reactors are in commercial operation in four countries.[60]

The CANDU reactor is a heavy water moderated, pressurized heavy water cooled reactor. The core consists of an array of horizontal pressure tubes surrounded by a low pressure calandria containing the relatively cool moderator (Figure 4). Natural uranium Zircaloy-clad fuel bundles are loaded and removed from the pressure tubes during operation by fueling machines operating at the two faces of the core. Heat is transferred from the heavy water primary system to a light water secondary system in vertical U-tube steam generators.



1. CALANDRIA
2. CALANDRIA – SIDE TUBESHEET
3. CALANDRIA TUBES
4. EMBEDMENT RING
5. FUELLING MACHINE – SIDE TUBESHEET
6. END SHIELD LATTICE TUBES
7. END SHIELD COOLING PIPES
8. INLET-OUTLET STRAINER
9. STEEL BALL SHIELDING
10. END FITTINGS
11. FEEDER PIPES
12. MODERATOR OUTLET
13. MODERATOR INLET
14. HORIZONTAL FLUX DETECTOR UNIT
15. ION CHAMBER
16. EARTHQUAKE RESTRAINT
17. CALANDRIA VAULT WALL
18. MODERATOR EXPANSION TO HEAD TANK
19. CURTAIN SHIELDING SLABS
20. PRESSURE RELIEF PIPES
21. RUPTURE DISC
22. REACTIVITY CONTROL UNIT NOZZLES
23. VIEWING PORT
24. SHUTOFF UNIT
25. ADJUSTER UNIT
26. CONTROL ABSORBER UNIT
27. ZONE CONTROL UNIT
28. VERTICAL FLUX DETECTOR UNIT
29. LIQUID INJECTION SHUTDOWN NOZZLE
30. BALL FILLING PIPE

FIGURE 4. CANDU REACTOR ASSEMBLY

Source: E. Siddall. 1983. The CANDU-PHW Reactor in Relation to a Second Nuclear Era, ORAU/IEA-83-11(M), p. 8. Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

Control of the CANDU reactor is maintained primarily through on-stream refueling. Computers control the routine plant operation.

The CANDU reactor is subject to many of the same potential accident initiators as a PWR. However, transients would generally occur more slowly because of the large thermal inertia of the moderator and pressure tubes. No PRA of a CANDU reactor has yet been reported, but it would be expected to be in the same range as that of a PWR.

The capital cost of a CANDU plant has been estimated to be about one-third higher than that of a light water reactor,[61] the main difference being the cost of the heavy water. The range of light water reactor capital cost is sufficiently broad, however, that comparisons are uncertain.[62] The overall economics of light and heavy water reactors are about the same, in view of the high availability and low fuel cost of the CANDU.

Recent studies[63,64] of "U.S. CANDU's" have been conducted by DOE and by EPRI. These studies indicate that CANDU reactors could be built and licensed for operation in the United States, but some design and licensing decisions could prove difficult. The pressure tubes, which contain full primary system pressure, do not currently conform to the American Society of Mechanical Engineers Pressure Vessel Code. If the tubes were required to have thicker walls, then slightly enriched fuel would be preferred to natural uranium. (The longer burnup achievable with enriched fuel gives it an economic advantage over natural uranium fuel in any case.) Other features which would be novel to the NRC include the seismic analysis of the core, the use of on-stream refueling and security problems related to continuous fuel handling, and computer control of the reactor.

The High Temperature Gas-Cooled Reactor (HTGR)

The experience gained in the operation of the Dragon Reactor in England, the Peach Bottom I Reactor of Philadelphia Electric, and the Arbeitsgemeinschaft Versuchs-Reaktor (AVR) in Jülich, Germany (all three were experimental reactors), and the Fort St. Vrain prototype reactor near

Denver provide a good basis for assessing the operability, maintainability, safety, and costs of high temperature gas-cooled reactors. The reference reactor design for commercial supply is a 2240 MWt (858 MWe) HTGR being developed by General Atomic under DOE contract.[65]

The HTGR is a helium-cooled, graphite moderated reactor assembled in a prestressed concrete pressure vessel (Figure 5). The primary system pumps and steam generators are located in cavities in the vessel. Fuel is in the form of graphite-coated uranium oxide or carbide particles in graphite blocks, dispersed in a large stack of graphite moderator blocks. The superior high temperature characteristics of the fuel and moderator allow the HTGR to generate steam at temperature and pressure conditions approximating those of modern fossil-fueled boilers.

The HTGR has some inherent safety advantages.[66] Probably most important is the relatively low power density of HTGRs--between 5 and 10 percent of that of a conventional PWR. Further, inasmuch as the fuel is dispersed throughout the moderator, the heat capacity closely associated with the fuel is over 100 times that for an LWR. Thus, in the event of an accident that interrupts the flow of coolant to the core, the elapsed time between the cessation of coolant flow and severe damage to the core (if no automatic or operator action is taken) is of the order of 10 hours in an HTGR, rather than tens of minutes for a PWR--a difference of more than an order of magnitude. One factor contributing to this is that lateral heat conduction through the graphite blocks in the HTGR core is sufficient to remove a substantial fraction of the afterheat from the core and carry it out through the reflector, from which the heat is radiated to the water-cooled steel liner of the reinforced concrete pressure vessel.

The HTGR's prestressed concrete pressure vessel has redundant load-carrying steel tendons which are readily inspectable and replaceable. The tendons keep the concrete and the vessel liner in compression. The vessel is designed to withstand 2400 psi, over twice its operating pressure. Should a crack form during a pressure transient, the resulting small gas leak would tend to be sealed when the gas pressure is reduced. Thus,

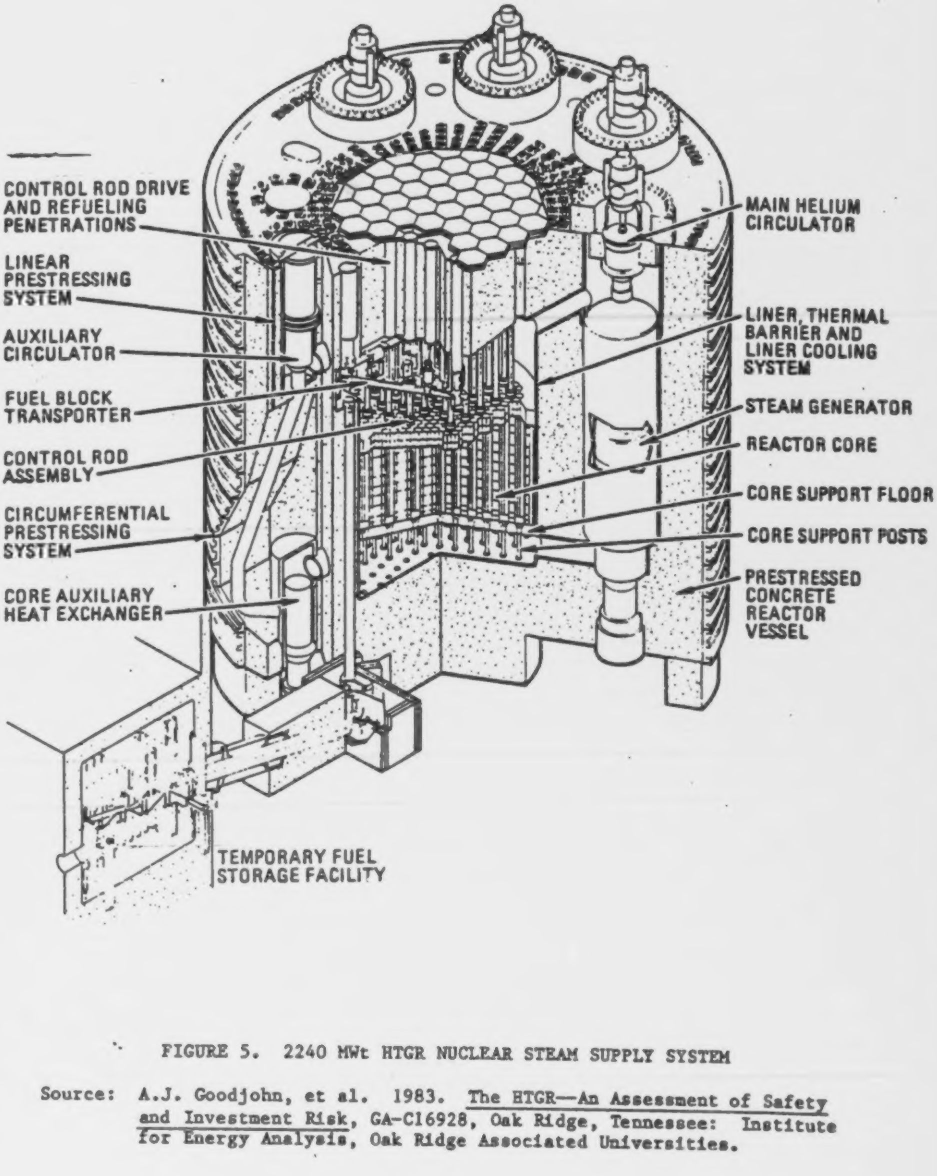

CONTROL ROD DRIVE AND REFUELING PENETRATIONS
LINEAR PRESTRESSING SYSTEM
AUXILIARY CIRCULATOR
FUEL BLOCK TRANSPORTER
CONTROL ROD ASSEMBLY
CIRCUMFERENTIAL PRESTRESSING SYSTEM
CORE AUXILIARY HEAT EXCHANGER
MAIN HELIUM CIRCULATOR
LINER, THERMAL BARRIER AND LINER COOLING SYSTEM
STEAM GENERATOR
REACTOR CORE
CORE SUPPORT FLOOR
CORE SUPPORT POSTS
PRESTRESSED CONCRETE REACTOR VESSEL
TEMPORARY FUEL STORAGE FACILITY

FIGURE 5. 2240 MWt HTGR NUCLEAR STEAM SUPPLY SYSTEM

Source: A.J. Goodjohn, et al. 1983. The HTGR—An Assessment of Safety and Investment Risk, GA-C16928, Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

catastrophic failure of the vessel is not possible under loads possibly imposed by the HTGR.

The HTGR has gravity-operated shutdown rods as well as an independent gravity-operated shutdown system. There is a dedicated emergency core cooling system for decay heat removal following a possible depressurization accident; this contains three redundant and diverse loops each capable of carrying the cooling load. Should the dedicated cooling system fail to operate, the liner cooling system (designed to keep concrete temperatures below code allowables during normal operation) is the ultimate protection for the reactor structure against a core heat-up accident.

The PRA of the reference HTGR indicates a fuel damage probability of 4×10^{-5} per reactor year,[67] comparable to those of PWRs. It should be recognized that the character of the fuel damage in an HTGR would be less severe than that in an LWR. The fuel and graphite structure remains basically as before, except some of the more volatile fission products escape the coated fuel particles into the gas stream. Severe accident analysis of HTGRs indicates that there would be damage to the heat transport systems in the event the dedicated core cooling systems fail and that there would be damage to the vessel should the liner cooling system be lost. However, most of the non-rare gas fission products are retained within the reactor vessel even in the worst accident scenario that has so far been envisioned.

Economic evaluations of the HTGR have tended to estimate its costs to be slightly higher than those of LWRs.[68] There are large uncertainties in these comparative estimates since the costs of LWRs have been increasing in response to regulatory changes while the impact of new regulations on the HTGR are often not apparent. Should the HTGR be exempt from certain regulations which are tailored to the needs of LWRs, its relative economics might be substantially improved.

The licensing of the reference HTGR could probably be readily accomplished readily since the NRC has licensed the Fort St. Vrain reactor and maintains an active HTGR evaluation program.

Inherently Safe Reactors

Although the previous sections indicate that, by skillful design and the liberal use of redundant components and systems, it is possible to evolve a system design giving a probability for a severe core damage accident of the order of 10^{-5} per reactor year or less, the resulting systems are very complex and the uncertainties that surround the PRA methodology are such that the absolute value of the risk is subject to debate. An alternate approach is to design a reactor that is inherently and transparently safe. The search for inherently safe reactors has been one of the main thrusts of the Second Nuclear Era study. Most of the effort has been devoted to a concept proposed by ASEA-ATOM of Sweden, the Process Inherent Ultimately Safe (PIUS) reactor. Another system which has received considerable effort is the modular HTGR. Several other concepts have been proposed but not reviewed in detail for lack of information.

The PIUS Reactor

In view of the Swedish moratorium on nuclear power, ASEA-ATOM decided in 1979 to go back to basic principles and design a light water reactor that would be incontestably safe to operate. Their criteria included not only safety from the standpoint of any conceivable accidents caused by equipment or operator failures but also safety from external events such as earthquakes and from sabotage or terrorist attack. This protection was to be had without calling into action any active safety equipment and without any human actions. The intrinsic protection should last a week or more to provide time for further actions to be taken. It was also desired that the plant could be operated after such an outage. Many experts have examined this new concept critically and have been unable to find any series of events, including sabotage and terrorist actions, that appear to have an appreciable probability of causing severe damage to the reactor core. Thus the system is perhaps unique and deserves special attention.

Description. The PIUS system is shown schematically in Figure 6. A large, prestressed, concrete reactor pressure vessel (PCRV) with a cavity diameter of 13 m and a cavity height of about 35 m encloses the entire primary circuit of a PWR. The containment vessel is filled nearly to the top with borated water so that virtually all of the primary circuit is immersed in a pool. The essential point of PIUS is a clever passive means of flooding the reactor with borated water if the core is in danger of losing coolant and of keeping the borated water out of the reactor during normal operation. This principle is also used in the district heating SECURE reactor, which is proposed for construction in Helsinki, Finland.

Both the primary circuit and the pool are maintained at a pressure of approximately 90 atm by the pressurizer of the primary circuit which is located in a steam region at the top of the cavity in the containment vessel. Inasmuch as the pressure drop in the primary circuit is just a few atmospheres, the envelope of the primary circuit separating it from the pool is required to carry only a small pressure differential. However, the hot primary circuit (which runs at 270°C) must be covered with a layer of thermal insulation to reduce the heat losses to the pool water (which runs at 50°C).

As can be seen in Figure 6, the system provides natural thermal convection since the reactor core is at the base of a hot water column about 30 m high. The density difference between the hot water in the riser above the core and the cold water in the pool is sufficient to give a pressure differential of about half an atmosphere. A large opening is provided between the primary system and the pool water at both the top and the bottom of the core-riser column. Honeycombs are provided in these open regions to inhibit convection currents, while the difference in density between the hot and cold water serves to maintain a stable position for the hot-cold liquid interface in each honeycomb under normal operating conditions.

Control. The system is designed for a constant water flow rate through the primary circuit and a constant reactor outlet temperature over

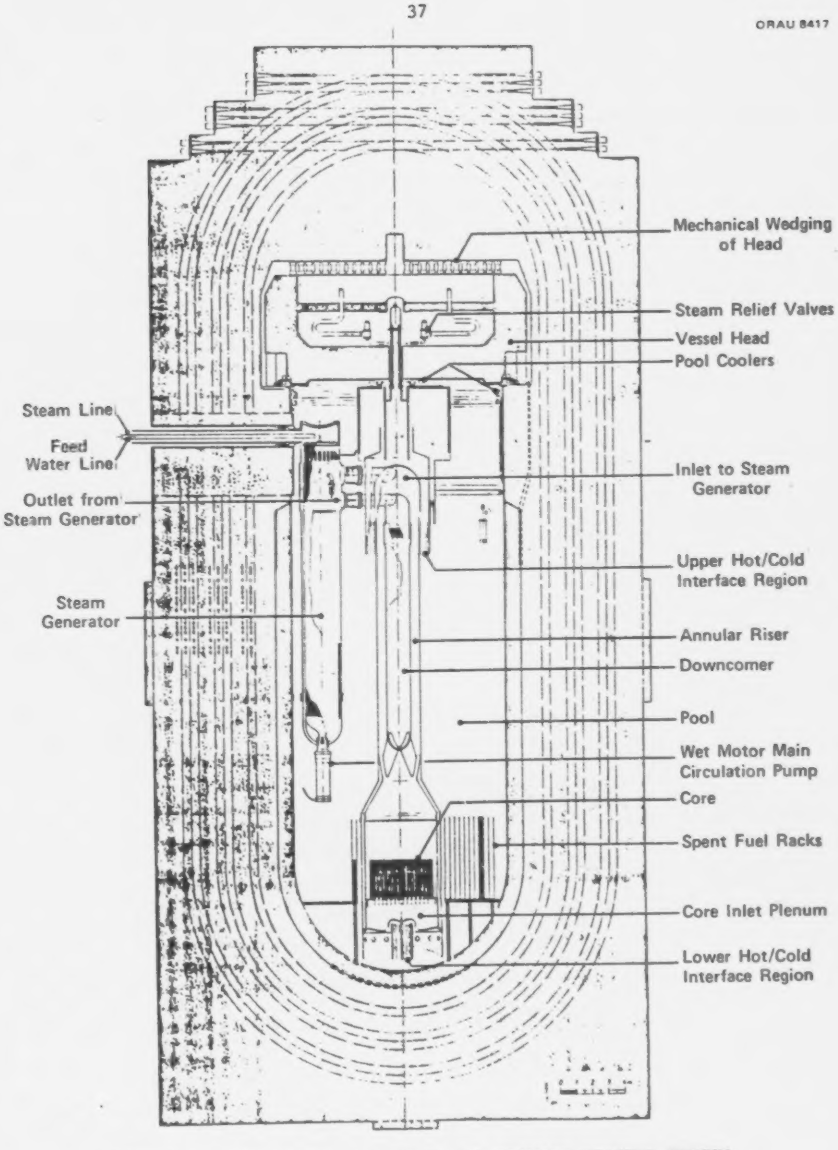

ORAU 8417
Mechanical Wedging of Head
Steam Relief Valves
Vessel Head
Pool Coolers
Steam Line
Feed Water Line
Outlet from Steam Generator
Inlet to Steam Generator
Upper Hot/Cold Interface Region
Steam Generator
Annular Riser
Downcomer
Pool
Wet Motor Main Circulation Pump
Core
Spent Fuel Racks
Core Inlet Plenum
Lower Hot/Cold Interface Region

FIGURE 6. PIUS CONCRETE VESSEL AND PRIMARY REACTOR SYSTEM

Source: K. Hannerz. 1983. Towards Intrinsically Safe Light Water Reactors, Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

the normal range of power operation. The circulating pumps for the primary circuit provide sufficient head to overcome the pressure drop through the primary circuit including the core and riser portion. The pump speed is modulated so that the pressure head available for flow through the core and riser is exactly equal to the difference in static head between the hot liquid in the core-riser column and the cold liquid column in the pool. Maintaining a constant water flow and a constant reactor discharge temperature means that the reactor inlet temperature drops as the power increases. The static pressure differential between the pool and the core-riser column does not have to be exactly balanced because the height of the honeycomb region is approximately 1.5 m. This serves to accommodate small variations in the difference in head available from the circulating pumps and the static head in the pool. However, in the event of any pump stoppage caused by a loss of electric power or a bearing failure, the flow through the primary circuit pump and steam generator stops, but thermal convection through the core will begin immediately because of the differential head available for natural thermal convection up through the core and riser and back down through the pool. Of course, as soon as this heavily borated cold pool water enters the core, the nuclear reaction is quenched. Note that no instrumentation and control equipment, valves, or pumps must operate to cope with an emergency. Further, there is sufficient water in the pool so that if there were to be a concurrent failure in the circuit acting to cool the pool water, the pool water temperature could rise to the point where a pressure relief valve at the top of the containment vessel would begin to release steam, and the afterheat generated from that point on would be carried off by evaporation of pool water. The capacity of the containment vessel is sufficient to provide cooling water for a week after such an accident before the level of the water would drop to the point where the core would be uncovered. Make-up water could then be added to the pool from fire trucks.

Protection from Terrorist Attack. The reactor vessel would be covered by a huge shield plug that could be moved out of the way only with special tooling. After this shield plug had been put in place over the reactor, the tooling would be disassembled and stored offsite so that no terrorist could employ it to remove the shield plug and sabotage the reactor. At least two days would be required to reassemble the tooling, and in that time it should be possible to cope with terrorists. An examination of this and other conceivable scenarios by several dozen experts has failed to yield any credible course of events that could lead to serious damage to the core and hence the potential for a substantial release of fission products. As a consequence, there appears to be no plausible sequence of events that could result in either serious damage to the core or a serious release of radioactivity to the atmosphere.

Crucial Problems. The principal concerns expressed by those who have reviewed the PIUS concept have been with respect to the stability and control of the interfaces between the cool pool water and the hot primary circuit (particularly under transient conditions), the capital cost of the large prestressed concrete pressure vessel, and the difficulties of maintenance through the deep water pool.

The basic design study in Sweden included the development of a digital computer model of the system and the investigation of a fairly wide variety of severe transients; the results indicated that the system was stable and the interfaces, well behaved under every condition considered. However, the various factors affecting the position of the hot-cold interfaces are surprisingly complex for this otherwise simple system, so much so that the computer model is quite involved and its validity uncertain. The question of interface stability is being investigated experimentally by the Tennessee Valley Authority in the United States and by ASEA-ATOM in Sweden.

The problems of maintaining the primary circuit equipment inside the pressure vessel in Figure 6 are certainly difficult. However, even in conventional PWRs, activity levels in the primary circuit are too high for contact maintenance, and special remote handling equipment must be developed. If such equipment were developed during the detail design of the

PIUS system, the overall costs of maintaining PIUS could be comparable to the costs of maintaining a PWR. The PIUS reactor would presumably avoid the continual testing and replacement of safety system components characteristic of a conventional LWR.

It is very difficult to estimate the cost of PIUS, which is still a concept and not even a design. The main new cost item in PIUS is the massive concrete pressure vessel. Although such vessels have been developed for water reactors in Sweden, the cost in a U.S. setting is uncertain. The amount of concrete and steel per kW of capacity in PIUS is expected to be in the same range as in some U.S. reactors.[69] The cost of the vessel tends to be offset by elimination of the safety systems and redundant equipment no longer required.

The commercial application of PIUS would require a staged development program to prove its feasibility and to demonstrate its licensability and operability. Since PIUS is a modified PWR, much technology already in commercial use could be applied. However, even under favorable circumstances it would take 8 to 9 years, according to ASEA-ATOM, to put a demonstration plant into operation. In view of the funding process for reactor development in the United States, we believe a realistic schedule for this country would be 12 years.

The Modular HTGR

Both Interatom in Germany and General Atomic in the U.S. have proposed modular designs[70,71] for a 250 MWt (100 MWe) unit that could be employed in groups, e.g., four would make up a 1000 MWt (400 MWe) plant. The small plants are similar to the large HTGR described earlier except that the primary system components can be housed in cylindrical steel vessels. The modular HTGR shares the attractive safety characteristics of the HTGR but does not require any active safety systems or human actions to protect the public in the event of an accident.

The power density in the modular HTGR is only 3 kW per liter, compared with a power density of 6 kW per liter in a standard HTGR, 60 kW per liter in a BWR, and 100 kW per liter in a PWR. Its extremely low power density confers on the modular HTGR a very high degree of safety. In the event of a loss of coolant accident the fuel temperature will not reach a high enough level to cause any major release of fission products. This characteristic of the modular HTGR qualifies it as being inherently safe.

The German design uses the same type of pebble bed core as has been operated successfully in the Arbeitsgemeinschaft Versuchs-Reaktor (AVR) at Jülich and is used in the Thorium High Temperature Reactor (THTR) under construction at Hamm-Uentrop. The AVR, a 15 MWe reactor, achieved power operation in 1968 and recently operated at 950°C for extended periods. It has been subjected to a variety of transients proving the fail-safe principles claimed for the modular HTGR.

The core of the German modular reactor is placed in one vessel, while the blower and steam generator are placed in a second vessel (Figure 7). The core diameter for the modular design was limited to around 3 m so that it is possible to get adequate reactivity control with just control rods in the reflector, i.e., with none in the core. This avoids the possibility that a control rod might become ineffective because it would fail to penetrate an unfavorable fuel ball configuration in the pebble bed.

The U.S. design is similar to the German design except that the reactor core is prismatic (similar to Fort St. Vrain) and the primary system components are mounted in a single vessel.

One advantage of the small size of the modular design is that a unit could be shop-fabricated and shipped to the site. The 250 MWt (100 MWe) unit, for example, has the reactor and steam generator installed in a cylindrical pressure vessel 6.2 m in diameter and 35 m high. Shop fabrication should lead to major reductions in cost and construction time as well as yield a higher quality product. These advantages of the modular design from the cost and construction standpoints might be offset by the increase in the amount of instrumentation and control equipment needed because each of the modular units would require a full set of such equipment and some additional equipment would be needed to operate a multiplicity of units in parallel.

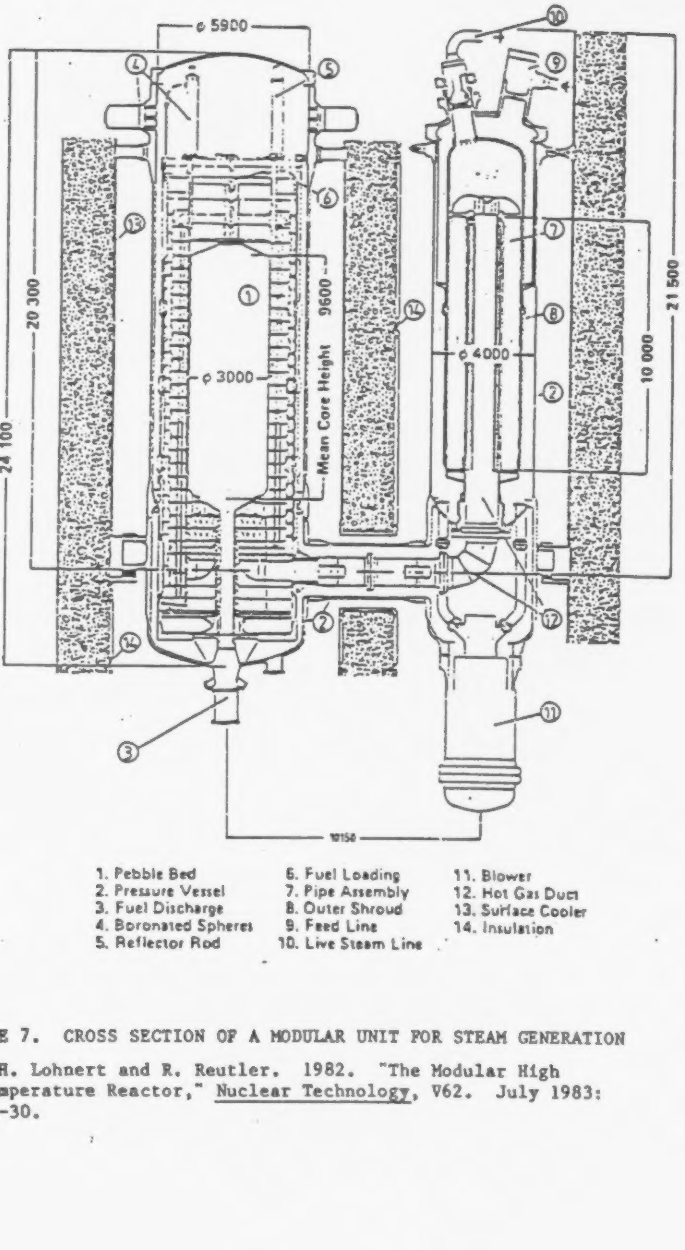

ø 5900
④
⑤
⑩
⑨
⑥
⑬
⑦
①
9600
Mean Core Height
⑭
⑧
20 300
ø 3000
ø 4000
21 500
10 000
②
24 100
⑫
②
⑭
⑪
③
10150
1. Pebble Bed
2. Pressure Vessel
3. Fuel Discharge
4. Boronated Spheres
5. Reflector Rod
6. Fuel Loading
7. Pipe Assembly
8. Outer Shroud
9. Feed Line
10. Live Steam Line
11. Blower
12. Hot Gas Duct
13. Surface Cooler
14. Insulation

FIGURE 7. CROSS SECTION OF A MODULAR UNIT FOR STEAM GENERATION

Source: G.H. Lohnert and R. Reutler. 1982. "The Modular High Temperature Reactor," Nuclear Technology, V62. July 1983: 22-30.

In view of the fail-safe nature of the modular plant, the German licensing authorities have ruled that the associated balance-of-plant equipment can be commercial grade as opposed to "reactor grade." This approach to licensing should improve the overall economics.

In the German design, the heat transfer systems and the reactor core are in separate vessels; this allows the plant to endure a temperature transient without serious damage to the heat transfer systems. This is not the case in the U.S. design, where all systems are in the same vessel; the more compact U.S. design should have a lower capital cost, however.

The critical uncertainties regarding the modular HTGR are the economics and commercial feasibility of the system, the scientific principles having been proven in the AVR. The U.S. Department of Energy and Gas-Cooled Reactor Associates in the United States and the German Government and KWU in West Germany are sponsoring development programs for the modular HTGR. However, the commercial potential cannot be established without the design, construction and operation of a prototype in the 100 MWe size-range.

Aside from commercial considerations, there are some very unlikely severe accidents which may cause radioactivity releases from the modular HTGR. These would be initiated by external events (earthquakes, explosions, terrorist attacks) which would break the primary system and expose irradiated fuel to combustion in air.

Other Inherently Safe Concepts

We have less information on other inherently safe proposals. However, we list them here to illustrate the variety of approaches to the elimination of serious accidents in reactors. None have been developed sufficiently to allow a serious estimate of practicality.

The Horizontal BWR. The General Electric Company examined a concept for a large natural circulation boiling water reactor in 1959.[72] The fuel rods were to be mounted horizontally in an eleven-foot diameter cylinder.

The power rating was to be determined by the number of modular sections of core, each with its own control rods and fuel assemblies. The concept was expected to develop 45 kW per liter of core (versus 56 kW per liter for a forced-circulation BWR/6). It is claimed that the reactor can be shut down by gravity forces without the use of rods and that shutdown heat can be removed by air cooling.

While this concept appears to be simpler and require fewer safety systems than a conventional BWR, we do not have sufficient information to determine whether its safety requires no active systems or operator intervention.

The Deep-well Reactor Concept. Westinghouse, in 1981, examined a concept for a natural circulation direct cycle reactor located 2100 feet below the surface.[73] The reactor is pressurized by the head of water above the core, and the core is cooled by liquid water which flashes on its way to the power conversion equipment (similar to a liquid geothermal cycle). In the event of a forced shutdown, safety rods go into the core and a large amount of pool water is available to remove decay heat through passive actions. Again, we do not have sufficient information to fully evaluate this system.

Inherently Safe LMFBRs. Edward Lantz, in a 1980 letter to Nuclear Safety,[74] proposed an "inherently safe" unpressurized pool-type, sodium-cooled reactor which would be controlled by the movement of bottom entry fuel assemblies. Free gaseous fission products would be removed continuously from the reactor to a naturally-cooled, well-protected site. Decay heat would be transported to atmosphere by presumably passive systems that would preclude fuel melting.

The Large LMFBR Pool Plant being studied by Rockwell International and Argonne National Laboratory[75] attempts to incorporate fail-safe features. This would allow the intermediate heat transport system to be nonsafety grade, a significant cost savings.

The development of an inherently safe, economical Liquid Metal Fast Breeder Reactor (LMFBR), appears to be a sufficiently reasonable long-term goal so as to deserve serious consideration. Birkhofer[76] reports the PRA of the German SNR-300 to show a core-melt probability of 2×10^{-6} per reactor-year. The LMFBR was not given prime consideration in the Second Nuclear Era study because it is a plutonium-fueled reactor; this limits its widespread deployment early in the twenty-first century. However, the LMFBR could become the primary source of fission energy later in the Second Nuclear Era if it were to meet cost and safety criteria.

The Pool-type Steam-cooled Reactor. M. A. Schultz and M. C. Edlund[77] have proposed a unique variation of the PIUS reactor that contains a plutonium-uranium oxide core at the bottom of a pressurized pool. The core is cooled by a fog which maintains reactivity at a natural maximum. If the amount of water in the core either increases or decreases, the reactivity decreases. The reactor is shut down with water flooding the core, removing decay heat to the pool as in the PIUS concept.

The steam-cooled reactor may be promising as a breeder or near-breeder for the long term. Considerable analytic study and development would be required to confirm and optimize the reactor design.

Selection of a Reference Inherently Safe Concept

It appears there may be a number of avenues to reach the goal of a relatively simple reactor design whose safety depends on passive, rather than active features. Some of these might be economic, especially if "nonreactor grade" standards could be used for the bulk of the plant's systems.

The PIUS concept was chosen as the reference for this study for a number of reasons:

1. It is a pressurized water reactor and can therefore utilize much of the experience gained in the commercial nuclear industry.
2. Enough design and analysis has been carried out on PIUS to eliminate the obvious challenges to safety.

3. It has superior resistance to external events such as sabotage, terrorism, and acts of war.

4. There is a reasonable chance that a SECURE reactor, the low pressure district heating version of PIUS, will be built in the next few years.

5. There is a plausible argument that PIUS costs would be reasonable.

The other inherently safe concept with a substantial engineering base, the modular HTGR, is also attractive. However, we have reservations about its resistance to some external events, such as terrorist attack and we are uncertain that its costs can be made competitive with LWRs or with coal plants; regulatory relief would help to bring costs down. We hope that development of the modular HTGR can be carried far enough for a firm cost estimate and for a convincing demonstration of its inherent safety.

The other inherently safe concepts suggested were not selected as the reference concept either because insufficient information had been developed or because they are based on plutonium fuel.

TECHNICAL REVIEW OF THE SAFETY OF REACTORS

Safety Institutions and Philosophy

Most early civilian reactors were similar to military ones or were prototypes of designs conceived to prove the feasibility of the various combinations of fuels, moderators, and coolants. By the late 1950s, two main product lines emerged: the pressurized water reactor (PWR) and the boiling water reactor (BWR). The 60 MWe Shippingport PWR was commissioned in 1957, the 200 MWe Dresden 1 BWR was commissioned in 1960, and the 175 MWe Yankee Rowe PWR was commissioned in 1961.

The chief players in the development of civilian nuclear energy in the 30-year period since 1950 were the Joint Committee on Atomic Energy of the U.S. Congress, the Atomic Energy Commission (now the Nuclear

Regulatory Commission and the Department of Energy), and the nuclear industry. The Reactor Safeguards Committee, now the Advisory Committee on Reactor Safeguards (ACRS), played a key role as the Atomic Energy Commission's reactor safety arm. In 1953, Edward Teller,[78] as head of the Reactor Safeguards Committee, stated that the ultimate responsibility for safe operation had to be placed on the shoulders of the owner-operators. In 1956, Willard Libby, the then-acting chairman of the AEC, indicated to the Congress[79] that the potential dangers of reactors to the public were large and that the ultimate safety of the public depended on three factors: (1) recognizing all possible accidents, (2) designing and operating the reactors in such a way that the probability of such accidents is reduced to an acceptable minimum, and (3) combining containment and isolation of radioactivity to protect the public should an accident occur.

In the early 1960s, the ACRS took the position that nuclear reactors must be safer than other contemporary technologies. Although efforts were not or could not be made in the 1950s and 1960s to delineate all possible accidents and to determine their probability of occurrence, reactor safety was assured through defense in depth. Thus, the fuel is encased in cladding, the core is protected from reactivity excursions, the heat is removed from the core, the core is cooled by an emergency system under upset conditions, and a containment building is placed over the entire primary reactor system to contain any accidental releases. Reactors are generally sited in locations with low populations, although a few were sited near large cities during a period when reactor designers and regulators were very confident in their ability to prevent severe accidents.

Reactor design criteria, developed over the years, are published in the Code of Federal Regulations (CFR), Title 10, Part 50, Appendix A.[80] There are 64 criteria covering reactor design from the fuel to the containment to the radioactive waste system. Safety system design is based on the single failure criterion, which stipulates that reactor safety must be maintained following a plant upset even if any one safety component fails to operate. The implementation of this criterion leads to several design concepts, including redundancy, diversity, and physical separation.

Although most other countries with nuclear reactors followed the United States' example, some, such as West Germany, Belgium, and Sweden established additional criteria. For example, the N-2 criterion stipulates that reactor safety must be maintained following a plant upset even if one safety component fails and another is out of service for maintenance. The 30-minute criterion stipulates that no operator interference is required in the first 30 minutes of the upset.

Other important U.S. design criteria include: quality assurance (Appendix B of 10 CFR 50), reactor vessel material (Appendixes G and H), radioactive waste release during normal operation (Appendix I), emergency core cooling (Appendix K), and fire-resistant design (Appendix R).

The result is that reactors are designed to withstand large internal and external accidents without subjecting the public to undue risks. The Design Basis Accident (DBA)[81] was stipulated to be the result of the double-ended rupture of the largest pipe of the reactor coolant system. The DBA served for a long time as a basis for equipment qualification and for siting new reactors. The DBA, however, does not cover the full range of possible accident conditions. For example, there are no provisions for events such as reactor vessel failure, degradation of the core cooling system to a point that a core melt will take place, or anticipated transients without reactor scram.

Operational Problems and Fixes

The development and demonstration stages of civilian LWRs lasted well into the middle 1960s. Confidence in the safe and economic exploitation of nuclear energy was high. Despite this attitude, there were a dozen or so incidents, both in the United States and in other countries, which caused severe damage to reactor cores. The majority of these reactors were experimental. The 3 MWt SL-1 Army reactor actually experienced a reactivity excursion and a steam explosion; 3 operators were killed.[82] However, the public during this period was largely in favor of nuclear energy.

An indication of the high degree of confidence in reactor technology was the vendors' design of newer, larger, and more sophisticated reactors without the benefit of extensive operating experience with smaller reactors. For example, General Electric designed the 200 MWe Dresden 1 in the late 1950s with the steam drum outside the reactor vessel. By 1966 it had designed the 1060 MWe Browns Ferry reactors[83] with the steam separators and dryers all within the reactor vessel. Westinghouse designed the Yankee Rowe reactor in 1958 for 180 MWe. By 1968 it had a contract for the Trojan reactor[84] at 1100 MWe. Perhaps even more remarkable, Combustion Engineering and Babcock and Wilcox started their present product lines in the middle 1960s with reactors in the 800 MWe[85] range, then increased the size to the 1300 MWe range[86] by the early 1970s.

As earlier reactors accumulated service experience, some operational problems developed. This is not unexpected in a new technology; the difference in the case of nuclear reactors lay only in that many hundred thousand megawatts of capacity had been ordered before these problems became apparent. The 1970s saw vendors and utilities trying to correct operational problems and the regulatory bodies trying to prescribe regulations based on lessons learned from these operational problems.

Some of the most notable operational problems with reactors include pipe cracking in the out-of-vessel recirculation lines of BWRs, fuel-clad interaction which limited load following capability, containment weakness of the BWR Mark I and II under Loss of Cooling Accident (LOCA) dynamic loading (now largely resolved), steam generator tube failure in early Westinghouse designs, sensitivity to the coolant system conditions in Babcock and Wilcox once-through steam generators, and water-hammer caused by the sudden collapse of steam in auxiliary feedwater manifolds. Many of these problems have safety significance and caused extensive investigation, retrofits, and additional costs.

Other operational problems were not safety-related but also caused extensive reactor downtime and eroded the economics of nuclear electricity vis-a-vis coal-generated electricity. Problems with the steam turbine and electric generator caused as much as 20 percent of major forced outages. These frequent shutdowns represent undesirable challenges to the safety systems.

From the safety viewpoint, operational events that may lead to core damage accidents are important. A systematic screening of some 19,000 licensee event reports covering some 400 reactor years over the period 1969-1979 revealed 52 such events, or 1 in every 8 reactor years.[87] Most well known among these events are the Browns Ferry fire (3/22/75), the Rancho Seco overcooling incident (3/20/78), and the Three Mile Island accident (3/28/79). Since TMI, other events took place that are also significant: the small-break LOCA at Crystal River (2/21/80),[88] the partial failure to scram at Browns Ferry (6/18/80),[89] the steam generator tube rupture at Ginna (1/25/82),[90] and the failure of the automatic reactor protection system at Salem (2/22, 2/25/83).[91]

The responses to these operational events have been mandated NRC fixes. For example, Appendix R to 10 CFR 50[92] was a response to the Browns Ferry fire and required extensive modifications to reduce the vulnerability of the control systems to fire. Many changes have resulted from the TMI accident as will be discussed later. Thus, nearly every reactor in the country has evolved into a unique design. This is in contrast to the situation in France or the Soviet Union where there are many reactors that are essentially identical.

The Rasmussen Reactor Safety Study

Early government support of the fledgling nuclear industry was not only the funding of research, development, and demonstration, but also the protection of the industry from third-party liability. The Price-Anderson Act, enacted in 1957, provides $560 million in liability insurance to partially mitigate this threat. The Price-Anderson Act represents an early recognition of risks associated with nuclear plant operations.

A study conducted in 1958, WASH-740,[93] indicated that if a 500 MWt reactor melted and breached the containment, it could theoretically kill 3400 people, injure 43,000, and cause $7 billion in property damage. As reactors increased in number and size, the results of WASH-740 were revised upward in 1967 but were not made public. By the early 1970s, however, there was pressure from many quarters to make a thorough review of the consequences of reactor accidents. The Reactor Safety Study was commissioned in 1972 with a charter to study the probability, as well as the consequences, of reactor accidents.

The Reactor Safety Study, headed by Professor Norman C. Rasmussen of the Massachusetts Institute of Technology, was carried out by experts from many organizations. It took 3 years to complete, was reviewed by many organizations and individuals, and was published in 1975 as WASH-1400.[94] The study examined the 810 MWe Surry PWR and the 1100 MWe Peach Bottom BWR as typical power reactors. It used the event tree technique to delineate accident sequences, used the fault tree technique to determine unreliability frequencies of safety systems and functions, and used probabilistic techniques to analyze data. The results of the study indicated that the median core-melt frequency for commercial PWRs is approximately 1 every 15,000 reactor years (6×10^{-5} per reactor year) and is uncertain by a factor of 5 in either direction. The corresponding prediction for BWRs is approximately 1 every 30,000 reactor years (3×10^{-5} per reactor year). WASH-1400 goes on to predict that a large release of radiation (here assumed to be over 10 percent of the iodine plus other selected fission products) would occur about once in every three PWR core melts and even more frequently for BWR core melts. Should the wind direction be toward a nearby center of population, the offsite casualties from such releases could number several thousand and property damage could be many billions of dollars.

WASH-1400 also revealed several previously little-noticed aspects of reactor safety. It pointed to the more frequent plant upsets, such as small-break loss-of-coolant accidents, system transients, and operator errors as important contributors to risk. The industry at the time was assuming that if a reactor system could deal with a large pipe break accident, then it could also deal with smaller ones. The study also confirmed the value of the emergency core cooling system, redundant power supply, residual heat removal, and containment.

Critiques of WASH-1400 came from several quarters. Industry claimed that WASH-1400 results were too conservative[95] and that deterministic criteria used in the licensing process were even more conservative. The Union of Concerned Scientists[96] complained that the WASH-1400 results were too optimistic and misleading and that actual reactor core-melt frequencies and consequences were higher, perhaps by an order of magnitude or more. The American Physical Society and the Lewis Review Committee (an independent peer review group appointed by the Nuclear Regulatory Commission)[97] praised the study for being a benchmark in safety methodology, pointed out that the study methodology was especially good for comparative analyses, recommended improvement through the study of licensee event reports, and recommended using the study's methodology in the licensing process. However, the Lewis review assigned larger uncertainties to the probabilities of accidents than were estimated in WASH-1400.

The Reactor Safety Study remained on the shelf and controversial for several years until the accident at TMI. This accident brought about increased interest in this study and its methodology.

The Accident at TMI and Its Repercussions

The accident at TMI has been described by many others, and we mention it here only because of its profound impact on the subsequent operation and regulation of reactors. TMI-2 is an 880 MWe Babcock and Wilcox reactor, owned by Metropolitan Edison of the General Public Utilities System, engineered by Burns and Roe, and constructed by United Engineers and Constructors. It started commercial operation in December 1978.

On March 28, 1979, main feedwater was lost (possibly caused by faulty inservice maintenance of the condensate polisher), and the safety rods shut down the fission reaction as designed. The primary system temperature and pressure increased because of the resulting inadequate heat removal from the steam generators. The pressure increase opened the pressurizer pilot-operated relief valve (PORV) as designed. When the primary system pressure dropped to 1700 psi, the high pressure safety injection (HPSI) system was actuated as designed. However, the PORV did not reclose as designed and the operators did not realize until 140 minutes later that this was causing a loss of coolant. Meanwhile, the operators misread the high water level in the pressurizer as an indication that the primary system (including the reactor vessel) was excessively filled with water by the HPSI. They throttled, then shut down the HPSI and opened the coolant letdown line, thus causing the reactor core to be uncovered. The core was severely overheated during this time; decay heat and metal-water reactions caused the exposed part of the core to slump. The reactor core was finally immersed in borated water 16 hours after the accident began.

Early in the accident, the relief valve of the tank receiving water from the pressurizer PORV opened, and radioactive water spilled onto the containment floor. This water collected in the sump, and the sump pump automatically pumped water to the auxiliary building, thus violating containment isolation. The tank receiving this water overflowed, spilling radioactive water on the auxiliary building floor with off-gas vented to the atmosphere. The total radioactivity release was estimated later to be about 2.4×10^6 curies of noble gases and 13 to 17 curies of iodine. The average radiation dose received by each of the 2.2 million people in the surrounding area was below 1.5 millirems; no one offsite is known to have received more than 70 millirems. This is small compared to the annual exposure of about 150 millirems most individuals receive from natural and medical radiation.

The accident disabled the TMI-2 reactor, and in the aftermath the NRC denied the sister TMI-1 reactor permission to restart. This is costly to Metropolitan Edison and the General Public Utilities system and to their customers.

There were many inquiries into the accident. The most important of these are the Presidentially-appointed Kemeny Commission[98] and the NRC-appointed Special Inquiry Group (Rogovin Inquiry).[99] Both inquiries concluded that "people problems" and "management problems" were the principal causes. They recommended that the NRC be restructured, that more efforts by the utilities and the NRC be put into training the reactor operators, that better equipment be available in the control rooms of reactors, and that emergency preparedness at the reactor sites be improved.

The NRC stopped licensing new reactors for a year as it devoted its attention and resources to the aftermath of TMI. It combined all recommendations into a plan called "TMI Action Plan." This comprises 347 detailed actions covering plant design, operation, and emergency preparedness. Implementation of the action plan has consumed NRC's attention and resources since TMI. As of early 1983, the NRC has largely been successful in implementing its TMI Action Plan. Ninety percent of the 198 priority items and 45 percent of the 149 other items had been implemented or were in the process of implementation; thus overall about 70 percent of the action plan is now in effect.

The NRC has several other programs that appear to be more vigorously pursued since TMI. The Inspection and Enforcement program annually makes some 3500 inspections of reactors in operation or under construction and has resident inspectors at each site. The Systematic Assessment of Licensee Performance program evaluates the licensee's reactor operation, personnel training, and corporate management. The resulting performance evaluations indicate considerable variation of quality of operation. The Systematic Evaluation Program assesses the needs of older reactors to satisfy the TMI lessons as well as other new requirements.

The NRC has also broadened its safety research program to include degraded core phenomena, radiological source terms, pressurized thermal shock, containment behavior, human factors, probabilistic risk assessment (PRA), and other areas not given emphasis prior to TMI.

Before TMI, the U.S. nuclear industry was very fragmented, with some 140 reactors (about 70 in operation and 70 under construction) manufactured by 4 vendors, engineered by over a dozen architect-engineers, constructed by some 20 contractors, and operated by about 60 utilities. Communications between utilities, chiefly through the NRC, were minimal.

Since TMI, the utilities have pooled resources to form the Nuclear Safety Analysis Center, the Institute of Nuclear Power Operations, and Nuclear Electric Insurance, Limited (NEIL). In addition, they expanded the number of owners' groups. All parties now realize that the industry must improve its internal communication to enhance learning and to address common technical and institutional problems.

The Nuclear Safety Analysis Center (NSAC) serves as a think tank for the industry on technical safety problems and their solutions. NSAC has extensively analyzed TMI and other accidents, has done research on the pressurized thermal shock phenomena, investigated NRC designated unresolved safety issues, and has participated in the industry's degraded core analysis program (IDCOR).

The Institute of Nuclear Power Operations (INPO) is chartered to promote quality reactor operation.[100] As of 1983, it had completed two rounds of evaluation visits at all operating reactors and is now embarking on the third round. Each such visit is conducted by a team of about 10 experienced people who spend two weeks at the site evaluating a list of operational areas, including corporate management of nuclear matters. The reports written by the team are discussed with operators and management for speedy resolution. INPO reports good cooperation in acceptance and response in the form of corrective actions. To enforce its recommendations, INPO uses the peer process: between evaluators and the evaluated, between the INPO president and the utilities' presidents, and between the INPO board of directors and the utilities' boards of directors. The last resort for resolving the remaining disagreement is referral of the case to the NRC and the insurance underwriters, a process INPO has not used thus far.

In addition to operations evaluation, INPO also evaluates reactors under construction, disseminates analyses of significant events, facilitates communication among utilities, promotes good operating practices, accredits utilities' training programs, and maintains data on safety events and nuclear plant equipment reliability.

TMI has demonstrated that the cost to the affected utility of an accident is very high even when no member of the public is hurt. The newly created NEIL[101] offers $415 million in excess property damage insurance (over the $450 million already available through other underwriters) and some $195 million towards the cost of replacement power. Each reactor now is covered by $560 million for liability and about $1.0 billion for property damage at an annual premium of between $6 and $8 million and promised contribution towards indemnification, should a mutually insured reactor suffer an accident.

The industry's owners groups[102] bring together utilities that own similar equipment and the vendors who manufacture that equipment. Some owners groups are BWR Owners' Group, Westinghouse PWR Owners' Group, Westinghouse Steam Generator Owners' Group, Babcock and Wilcox Owners' Group, and Combustion Engineering Owners' Group.

The reactor vendors have also been hard at work since TMI to service their reactors. For most reactor vendors the service business now dominates; reactor design has dropped to second place as backlogs have cleared and new orders have not arrived. Some notable equipment marketed by the vendors since TMI includes the core water level monitoring system, the hydrogen mitigation system, the safety-grade power supply for the pressurizers, and the radiation monitoring systems. Vendors have also developed new reactor systems described in the previous section.

In retrospect, TMI revealed flaws both in nuclear safety technology and in safety philosophy: reactor deployment had been expedited without extensive operational experience; design for safety was too narrowly focused; rules and regulations were developed after, rather than before commercial reactor deployment; the industry was fragmented and tended to rely on the Nuclear Regulatory Commission for safety guidance; information was not effectively shared; and not enough attention had been given to the human aspects of reactor operation and public reaction to the spectre of a reactor accident. But the response to TMI by industry and government has been significant. There is little doubt that reactors today are safer than they were before TMI.

The Nuclear Source Term*

The experience at TMI and at other reactor accidents, together with experiments that have been conducted recently, show that the source term of WASH-1400 (0.3 billion curies of noble gases and 0.9 billion curies of non-noble gas fission products) greatly overstates the probable release of radioactivity.[103] The source term is currently under intense review by NRC and it is not possible to predict the outcome of the review. However, our analysis of the data indicates that the largest catastrophic release of WASH-1400 cannot be ruled out but their frequency has been overestimated by a factor of 20; it should be 5×10^{-7} per reactor year instead of 10^{-5} per reactor year.[104] The most likely large release of non-noble gas fission products is reduced in magnitude by a factor of ten (to about 0.08 billion curies) and in frequency about a factor of 2 to 5×10^{-6} per reactor year.

The largest release which could occur at the Surry PWR, according to WASH-1400, would cause 350 to 6200 early fatalities, depending on the effectiveness of evacuation. There would also be 1400 latent cancer fatalities. As discussed in the preceding paragraph, the most likely large release in our analysis would have a factor of 10 fewer non-noble gas fission products; this would limit early fatalities to 3 to 60 and latent cancer fatalities to 140.

---

*The Nuclear Source Term is defined as the radiological emission which is anticipated after a core damage accident in a nuclear reactor. The source term is of interest because it is the principal hazard to the public resulting from the operation of nuclear power plants.

The very large catastrophic release requires an early breach of containment either before or shortly after the core melt. There are very few mechanisms available for this early failure; they include a massive missile or earthquake, or overpressure from steam and/or a hydrogen explosion. If containment failure can be delayed for an hour or more after the core melt, then the fission product aerosols within the containment settle and the source term is reduced. A relatively innocuous source term results if containment failure is averted for a day or more.

To summarize, we believe the data justify a significant reduction in the seriousness and probability of large releases from LWRs, though we cannot rule out the possibility of a very large release.

The Safety of Reactors Before and After TMI

Qualitatively, U.S. LWRs after TMI are much safer than they were before TMI because of TMI lessons learned, hardware retrofits, and better and more uniform operating procedures. To estimate quantitatively how much safer reactors are today than before TMI, we catalogued the core-melt frequencies resulting from the four most important event trees for BWRs and PWRs in three cases:[105] before TMI, WASH-1400, and after TMI. The four event trees include small-break LOCA, loss of offsite power (T_1), system transients other than T_1 that leave the power conversion system (PCS) inoperative, and system transients other than T_1 that leave the PCS operable. These event trees account for over two-thirds of the total accident probability.

System unreliability values for each safety function of the event trees were determined for the three cases: the before TMI case by using values from the Oak Ridge National Laboratory-Science Applications Inc. (ORNL-SAI) precursor study[106] for the period 1969-1979; the WASH-1400 case by using values from WASH-1400; and the after TMI case by using values from the Indian Point PWR PRA[107] and Limerick BWR PRA.[108] Reconciliation of data was made where necessary by also consulting the INPO and SAI critiques of the ORNL-SAI study.

Our results indicate that the core-melt probability of reactors before TMI was perhaps twice the estimate in WASH-1400, but that improvements incorporated into reactors since TMI have reduced the probability to 1.5 to 3 times below the WASH-1400 estimate. This combines to make the core-melt probability of reactors after TMI 3 to 6 times lower than that before TMI. The actual computed ratio is 6 for PWRs and 3 for BWRs. The median core-melt probability for PWRs is higher than for BWRs in all three cases--before TMI, WASH-1400, and after TMI.

As for risk to the public, post-TMI LWRs have benefited from reduced core-melt probability (factor of 5), reduced source term as the result of more accurate prediction (factor of 20), and greater attention paid to emergency planning (factor of 2). The risk to the public from a current post-TMI reactor is thus at least 10 times and possibly 100 times less than that presented in WASH-1400, which already predicted a low risk compared to other societal risks.

Though these estimates suggest that post-TMI reactors are quite safe, we must point out that estimates of core-melt probability are inherently uncertain and such uncertainty alone raises the estimated core-melt frequency for a given number of reactor years. For example, we find that if the probability of a core melt per year be log-normal with a median equal to 1.7×10^{-5} per reactor-year and an error factor of 10 (roughly, the median could be 10 times too high or too low), then the expectation of a core melt in 9000 reactor years would be 0.23; whereas if the error factor were 1, the expectation would be 0.14.[109] We find it reassuring that even very large uncertainties with the same median in the estimated core-melt probability would hardly double the estimated expectation value of a core melt over the next 20 years for a 500-reactor world, provided the assumption of log-normal probability distribution is justified.

Future Directions for Reactor Safety

The NRC, following TMI, has proposed a goal of 10^{-4} per reactor year for the core-melt probability as estimated by PRA. There is no doubt that the majority of LWRs today meet this criterion. These reactors can also satisfy the goal of adding not more than 0.1 of 1 percent to all other risks confronting society or individuals. Can we therefore conclude that today's reactors are safe enough?

In a 500-reactor world, one might expect a meltdown every 20 years in reactors satisfying the safety goal. As the number of reactors increases in a Second Nuclear Era, the likelihood of a meltdown would also increase. Though posing little risk to the public at large, a meltdown of any one nuclear plant could pose many risks to all investors in nuclear power. We propose, therefore, that as the number of reactors increases, the safety goals should be tightened for new reactors.

Reactors already being developed, such as the Sizewell B PWR, the APWR, and the ABWR appear to have a desirably low meltdown probability. However, safety is gained through increased redundancy and complexity as compared to present already complex designs. We are disappointed that there is no sponsor, in industry or in government, for development of a low-cost light water reactor that is simple to operate and maintain, and where safety is assured through a few fundamental and easily understood features.

Such features include the following:

1. reliable shutdown systems that eliminate the anticipated transient without scram (ATWS) problems

2. reliable primary water supply to keep the core covered, and reliable level measurement

3. reliable, dedicated, shutdown decay heat removal systems

It can be argued that if the above features are assured, then any other malfunction would not damage the fuel. Hence much of the rest of the nuclear plant can be built to conventional engineering standards at lower cost. Until the NRC accepts this argument and modifies the present prescriptive mode of regulation, the industry would have little incentive to support detailed design of such plants.

Our analysis of the source term indicates that public risk might be further reduced or virtually eliminated through improved containment design. The objective would be to eliminate those failure scenarios that lead to early rupture or bypass of the containment. German containment designs may already accomplish these goals.

We also favor judicious selection of reactor sites in low population areas insofar as possible, as a means of reducing both public risk and public apprehension.

We believe the measures we advocate are needed to reduce risk and cost on the part of the investor, and to contribute to improved confidence in nuclear power on the part of the public and elected officials.

THE ECONOMICS OF NUCLEAR POWER

The continuing cancellation of partially completed nuclear power plants provides eloquent testimony to the mismatch between the economic/financial characteristics of nuclear power plants and the utilities' present criteria for generating capacity. Yet, nuclear reactors generate the lowest cost power in many utility systems. This section of the report summarizes the economic record of operating reactors, of plants under construction, and examines present and future trends.

It is obvious that the economic/financial characteristics of nuclear power plants must be made consistent with the perceived needs of utility investors for there to be a Second Nuclear Era.

Economics of Operating Nuclear Reactors

As of June 1983 there were 82 power reactors operating in the United States with a capacity of about 66,000 MWe and supplying about 13 percent of the nation's electricity. The national average costs of electricity generation by these reactors (including fixed charges, O&M, and fuel) have been consistently lower than those of coal-fired power plants (6 percent lower in 1976, 25 percent in 1977, 32 percent in 1978, 17 percent in 1979, 8 percent in 1980, 16 percent in 1981, and 11 percent in 1982, as shown in Figure 8).

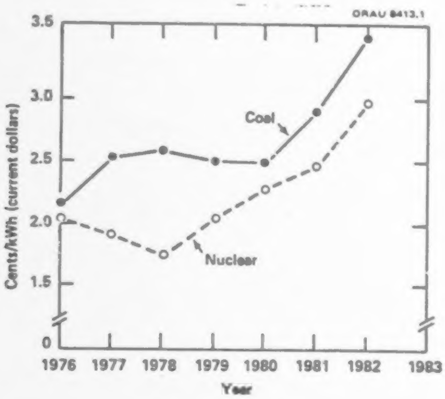


FIGURE 8. TRENDS IN AVERAGE COSTS OF COAL AND NUCLEAR ELECTRICITY IN THE UNITED STATES

Source: Economics of Nuclear Power: Past Record, Present Trends, and Future Prospects, ORAU/IEA-83-13(M). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

For most utilities with large nuclear, coal-fired, and oil-fired capacities, nuclear plants have economically outperformed the others. For the years 1981 and 1982, the nuclear electricity generated by the Tennessee Valley Authority was cheaper than coal-fired electricity by 45 percent and 47 percent,[110] respectively. At Commonwealth Edison, the generation cost from six nuclear reactors was only half that of either six comparable coal-fired plants[111] of the same size and vintage or of the system-wide coal-fired capacity (1980).

The majority of these operating reactors were on-line before 1978. Most were ordered in the late 1960s when utility executives' and public confidence in nuclear power was high. Licensing at that time was relatively simple. Reactors were simpler than today's new plants. Vendors were selling reactors inexpensively, partly because of their inexperience these reactors at the time of commercial operation was low. For example, the two Dresden reactors cost $146 per kW in 1971, the two Point Beach reactors cost $160 per kW in 1972, the two Zion reactors cost $279 per kW in 1974, the three Oconee reactors cost $181 per kW in 1974. In terms of 1983 dollars, nineteen General Electric operating reactors cost an average of $482 per kW, nine operating Babcock and Wilcox reactors cost an average of $614 per kW, seven operating Combustion Engineering units cost an average of $715 per kW, and 24 operating Westinghouse reactors cost an average of $622 per kW.[112]

The reactors built in earlier years have been extensively retrofitted. Data for 35 reactors indicate that an average of $156 per kW or 28 percent of the adjusted initial capital cost have been or are in the process of being spent on retrofits. Over 60 percent of the costs are attributed to regulatory requirements, most notably on items related to fire resistance (following the Browns Ferry incident), BWR containment (Mark I) modifications, earthquake resistance, emergency power reliability, and security assurance. Less than 40 percent of the retrofit costs were initiated by the owner-operators to improve operability. Utility-initiated retrofits include expansion of onsite spent fuel storage, steam generator and condenser fixes or replacement, and facilities for the increased number of onsite personnel. Surprisingly, TMI-related retrofits do not appear to be as expensive as is often claimed by industry. For the Northeast Utilities' three reactors (Connecticut Yankee, Millstone 1, and Millstone 2), the TMI-related retrofits constitute $25 per kW or 12 percent of all retrofit costs; other regulatory retrofits and utility initiated retrofits making up 50 percent and 38 percent, respectively. For the Commonwealth Edison six nuclear plants (Dresden 2 & 3, Quad Cities 1 & 2, and Zion 1 & 2), the TMI fixes cost $12 per kW or 16 percent of all retrofit costs. Other regulatory and utility retrofits amounted to $50 per kW (66 percent) and $14 per kW (18 percent), respectively.[113]

The availability factors of the operating reactors on the average have been slightly over 70 percent, the capacity factors around 56 percent.[114] The difference between availability factor and capacity factor is the result of operation at below rated load at the discretion of the utility, or because of NRC-mandated cutbacks. The shortfall in the average capacity factors—about 15 points below the best reactors—is due to a variety of reasons: pipe cracking in the primary circuits, water chemistry in the power conversion circuits, steam generator deterioration, steam turbine warping, generator instability, refueling, and NRC-mandated cutbacks. As the reactors mature and retrofits are made, these problems lessen, but it is doubtful whether the overall lifetime capacity factors of these reactors would be much over 65 percent. There are exceptions: the Connecticut Yankee (600 MWe PWR) has been operating since 1968 at the cumulative capacity factor of 75 percent. The six reactors in Minnesota and Wisconsin have been operating since the early 1970s at a cumulative capacity factor of 73 percent.[115]

The overall availability and capacity factors of nuclear plants are on the average equivalent to those of coal-fired plants. The National Electric Reliability Council[116] has compiled these factors for coal-fired and nuclear units in several size categories. The conclusion is that for the period 1971-1980 nuclear reactors smaller than 800 MWe performed better than comparable coal-fired units, while those larger than 800 MWe performed slightly worse than comparable coal-fired units. Both types of generation provide capacity factors averaging 55 to 60 percent in the United States.

Nuclear fuel costs have been around 0.3 to 0.6 cents per kWh, or less than half those of coal during the 1970s. Uranium prices rose precipitously in the mid-1970s but fell back to less than $25 per pound of yellow cake when it was clear to the commodity market that there was plenty of uranium supply for the projected nuclear capacity. Enrichment cost increases (to above $125 per separative work unit) and cost allowances for spent fuel storage and long-term radioactive waste disposal have more than offset reductions in yellow cake prices. Nevertheless, for plants already on-line as of 1982, the fuel portion of nuclear electricity averages only about 25 percent of the generation cost, while that of coal represents about 50 percent. Operation and maintenance (O&M) costs were about 0.2 to 0.3 cent per kWh. These costs have increased faster than general inflation due to increased requirements: more and better operators, high maintenance costs, and special technical services. The O&M costs are expected to increase further to 0.5 to 0.6 cent per kWh due to the TMI actions and to the increased requirements for and availability of insurance.

Economics of Nuclear Plants Under Construction

About 57 reactors are now in advanced stages of construction.[117] Reactor licensing became increasingly complicated as new regulations were imposed on plants under construction. Requirements for concrete, steel, cables, engineering manhours, and labor manhours to build a typical reactor plant have doubled or even tripled over a 10-year period because of the increased regulatory requirements and the inefficient use of labor resulting from constantly changing designs (Table 1). The interval from decision to commercial operation also doubled, from approximately 6 to 7 years to as long as 14 years. Interest rates on borrowed funds to pay for construction have increased, sometimes to above 15 percent per year.

The management of nuclear projects has been of variable quality. Some aggressive utilities such as Commonwealth Edison, Florida Power and Light, and Arizona Public Service (and partners) were able to build their nuclear plants within reasonable schedules and costs (6 to 7 years and $1200-$1500 per kilowatt). (The Arizona Public Service's Palo Verde project has apparently experienced a six-month delay because of primary pump defects. This setback has been estimated to increase capital costs about $200 per kilowatt.[118]) Others ordered a nuclear plant for the first time and tended to treat nuclear projects in the same way small coal-fired plants were handled in the era prior to the National Environmental Policy Act. They relied heavily on architect-engineers, consultants, and contractors, some of whom were not themselves well prepared to design and

TABLE 1. INCREASED REGULATORY, MATERIAL, AND LABOR REQUIREMENTS FOR U.S. NUCLEAR PLANTS

Escalation of codes, standards, regulatory guides, bulletins

	No. of Standards	NRC Guides & Positions
1970	400	4
1973	1074	68
1975	1624	157
1978	1800	304

Increased material requirements

	Concrete (Cubic Yards)	Steel (Tons)	Cable (Yard)	Cable Tray (Yard)	Conduits (Yard)
1973 estimate of 1981 operation	90,000	15,400	670,000	8,400	58,000
1978 estimate of 1985 operation	162,000	34,200	1,267,000	27,000	77,000

Increased labor requirements (manhour/kW)

	Engineering	Craft	Total
1967 estimate	1.3	3.5	4.8
1972 estimate	3.4	6.2	9.6
1978 estimate	5.5	13.0	18.5
1980 estimate	9.2	19.3	28.5

Source: D.L. Phung. 1983. Economics of Nuclear Power: Past Record, Present Trends, and Future Prospects, ORAU/IEA-83-13(M), p. 14. Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

build nuclear plants in a changing licensing and social environment. Some of the consequences were mistakes, delays, workers' unrest, citizens' protests, litigation, stopped work, and rework. Costs spiraled to twice or more those of the best projects.

The unfavorable factors caused a cash flow shortage in most utilities that have nuclear plants under construction. Local public service commissions and/or state legislatures have often disallowed rate increases and funding of construction work in progress (CWIP). As a result, bonds of many utilities have been derated and market prices of stocks in many cases are below book values. Under these circumstances, many utilities have had to delay, mothball, or cancel reactors under construction, many in advanced stages. The Tennessee Valley Authority (TVA) is writing off $2 billion expended on four reactors cancelled while under construction; four others are deferred. The Washington Public Power Supply System (WPPSS) has had to cancel or defer four of its five reactors and was forced into default on some of its bonds.

The approximately 57 surviving reactors that will go commercial within the next five years will double the nuclear plant capacity from the current 64,000 MW to about 123,000 MW.[119] Their costs will range from $1100 per kW to $3500 or more per kW, with the average around $1700 per kW (1983 dollars). The lower costs are those of reactors such as Braidwood 1 & 2, St. Lucie 2, Palo Verde 1, 2, & 3 (assuming the pump problem is not too costly), which were well managed, purchased at favorable terms, engineered by experienced architect-engineers, and suffered relatively few problems during construction. The higher costs are those of reactors such as Shoreham, South Texas 1 & 2, Midland 1 and 2, and Zimmer, which have suffered extensive problems with quality assurance, poor management, labor unrest, citizen protest, and regulatory confusion.

While regulatory-mandated retrofits are expensive to operating reactors (about 28 percent of original cost adjusted to 1983 dollars), the impacts of increased safety requirements on reactors under construction have not been quantified. The Atomic Industrial Forum (AIF) estimated that the post-TMI improvements cost these reactor operators about $40 million for each reactor,[120] or approximately 2 to 3.5 percent of the capitalized cost.

These new reactors, when brought on-line, will cost four to six times the costs of older reactors. When adjusted to include inflation and backfits, the cost ratio is still about 3. The sudden inclusion of such huge new capital outlay into the rate base, often increasing it as much as 100 percent, results in a very substantial sudden increase in electric rates ("rate shock"). Thus, nuclear plants, touted earlier as generators of cheap electricity, in a number of cases are bringing about large rate increases.

Even so, the majority of reactors that are about to go commercial will probably generate electricity at a cost equal to or cheaper than that of comparable coal-fired plants. Even if the coal-fired plants are only two-thirds as capital intensive as nuclear reactors, the cost of coal must stay below 2.5 cents per kWh (or $2.5 per million Btu) in 1983 dollars for the next 30 years in order to be competitive with these reactors. But the price of coal will almost surely rise: acid rain abatement, railroad rate increases, scrubber slurry disposal, and coal mine reclamation are but a few factors that will contribute towards cost increases of coal-generated electricity. For example, the National Economic Research Associates, Inc.,[121] estimated for the Edison Electric Institute that passage of acid rain legislation now pending before Congress would cause electric bills at 24 utilities east of the Mississippi to rise between 5 and 38 percent per year (on the average less than 10 percent) over the first five years of adoption.

Trends Affecting the Economics of Nuclear Power

A recent DOE comparison of projected capital cost for 1995 coal and nuclear plants is given in Table 2. The expected capital costs in 1995 dollars are rounded to $4700 per kilowatt for nuclear and $3000 per kilowatt for coal. These costs presume a status quo in both regulation and

TABLE 2. POWER PLANT CAPITAL INVESTMENT COST ESTIMATES FOR COMMERCIAL OPERATION IN 1995 (dollars per kWe)

	Nuclear 1 x 1200 MWe	Coal 2 x 600 MWe
	Direct costs (January 1982 dollars)	
Land and land rights	5	5
Structures and improvements	190	75
Reactor/boiler plant	240	340
Turbine plant	190	160
Electric and other	155	105
Subtotal (direct costs)	780	685
	Indirect costs (January 1982 dollars)	
Engineering and construction services	495	135
Owners' costs	125	85
Subtotal	620	220
	Total Costs (January 1982 dollars)	
Direct and indirect costs	1400	905
Contingency allowance	210	135
Total "overnight" cost (Jan. 1982 dollars)	1610	1040
	Time-related Costs (in mixed dollars)	
Escalation (as-spent dollars)	1440	1155
Interest (as-spent dollars)	1610	755
	Total Costs (1995 dollars)	
Plant capital cost at time of commercial operation	4660	2950

Key assumptions:

inflation rate, 6% per year
escalation rate of power plant construction cost, 8% per year
average cost of money, 11.9% per year
overall schedule, 12 years for nuclear, 8 years for coal

Source: Energy Information Administration. 1982. Projected Costs of Electricity from Nuclear and Coal-fired Power Plants, DOE/EIA-03561, August 1982, Washington, D.C.

institutional arrangements. Under these circumstances, nuclear power and coal are roughly competitive at coal prices of $2.50 to $3.00 per million Btu (1982 dollars) presuming coal price inflation at 1.5-2 percent above general inflation. The cost of generation from these plants is projected to be 5 to 5.5 cents per kWh in 1982 dollars (nearly twice the average nuclear generation cost in 1982).[122]

Utility executives are not likely to commit their companies to build any further nuclear reactors in the short term, possibly up to 1990. There is an excess of capacity, sometimes as much as 40 percent on many systems. Reduced economic activity, price-induced consumer conservation and active utility-sponsored conservation programs continue to keep growth in demand low. Reactor licensing, while showing some stability, is still far from predictable. Capital cost estimates for new projects are high (as illustrated above), while projected cash flows are uncertain. Reactors are too large in size relative to projected firm load growth, too complicated, and pose a high financial risk.

On the other hand, there are trends encouraging to the future economics of nuclear power. Inflation has been drastically reduced since 1981, and it appears that it may stay low for some years to come. Interest rates were extremely high between 1981 and 1983 but have come down to the 12 to 14 percent range. The public utility commissions (PUCs) in many states are sympathetic with the plight of electric utilities and have allowed sizable rate increases; for example, $6 billion in 1980 and $8.3 billion in 1981. Some PUCs, such as those of North Carolina and Pennsylvania, allow a rate of return on stockholders' equity up to 16 to 17 percent. Other PUCs allow an incentive payment to utilities that complete a construction project within a specified cost range.

Allowance for construction work in progress (CWIP) is now increasingly accepted as a means to limit capital cost increases and future rate shock. In 1967, only 6 percent of the $170 billion of capital outlay was covered by CWIP. In 1973, 18 percent of $225 billion was covered by CWIP, and in 1981, 25 percent of $280 billion.

CWIP would shave as much as 30 percent off the capitalized costs of power plants at the time of their commission and would thus avoid rate shock and would save money in the long run. Nuclear plants benefit more than coal-fired plants because of their higher capital cost--nuclear plants cost 30 percent to 50 percent more than coal-fired plants. However, Asbury[123] of Argonne National Laboratory has calculated that 100 percent CWIP allowance would increase electric bills of current consumers by 5 to 14 percent per year. Rate-setting bodies constantly face the dilemma of balancing high costs today against higher costs in future years.

But better times for nuclear energy could be just beyond the horizon. Factors influencing this prospect include a grassroots tendency towards electrification (i.e., industrial processes, residential space heating), improved management of the nuclear enterprise, legislation designed to resolve radioactive waste management, licensing reform, and better reactor designs.

In 1982 at the instigation of the White House (Vice President George Bush) several U.S. agencies under the leadership of the Department of Energy undertook a study[124] on the adequacy of electricity supply in the United States to the year 2000 and beyond. The study found that while there is a current surplus of installed capacity, 25 percent of the capacity is still fired by oil and gas and 25 percent is over 20 years old. At a medium demand growth rate of 3 percent per year, 330,000 MW of capacity should be built by the year 2000. In addition, high market prices of oil and gas dictate that some 40,000 MW of capacity that burn these fuels should be replaced. Replacement of older units would require a further 70,000 MW. Thus, a total of about 440,000 MW of capacity might be required by the year 2000, of which only about 150,000 MW have been ordered, leaving some 290,000 MWe to be ordered, perhaps by the late 1980s. A 2 percent growth scenario would lead to approximately 160,000 MW to be ordered.

We note that these forecasts of the Department of Energy study are not universally accepted, even within DOE. The projected needs for new base-load plants might be reduced by recession, increased conservation, more reliable operation of the existing plants, more power interchanges, co-generation, and so on.[125] On the other hand, current electric load forecasts are too low should the U.S. economy continue to expand. The point is that load growth is a necessary but not sufficient condition for a Second Nuclear Era. Should load growth occur, then we would hope that the Government, the industry, and rate-setting bodies will work together to improve the economic framework for nuclear (and coal) power delivered to the consumer.

Prospects of Nuclear Power Economics in the Second Nuclear Era

By the start of the Second Nuclear Era (say, the year 2001), the first generation of nuclear plants and many coal plants will have mostly been paid for. If demand growth has been limited to 2 to 3 percent per year, electricity rate increases to consumers will probably be modest. Indeed, if the generating system continues to operate well, the real cost, if not the price of electricity may actually fall.

The technology now exists to build better and safer reactors. The Advanced Pressurized Water Reactor (APWR) now under design by Westinghouse and Mitsubishi and the Advanced Boiling Water Reactor (ABWR) now under design by General Electric and Toshiba both have superior safety features that reduce the median core-melt frequency to perhaps 10^{-6} per reactor year. The High Temperature Gas Cooled Reactor (HTGR) appears to be as safe as the safest LWR and appears less susceptible to massive fission product releases thanks to the superior temperature resistance and high heat storage capacity of the large graphite-moderated core. The small modular HTGR provides "walkaway" safety and is much safer than a large HTGR. The Process Inherent Ultimately Safe (PIUS) reactor appears to be incapable of a core melt under even the most adverse conditions, such as sabotage, abandonment (for up to 7 days), and conventional acts of war.

Will these new reactor designs be economic? The competitive nature of our economy suggests that the APWRs, ABWRs and coal will be priced to be competitive. The Gas Cooled Reactor Associates (GCRA),[126] under a grant from the Department of Energy (DOE) to study the feasibility of an HTGR for South Florida, believes that the equilibrium HTGR (not the first-of-a-kind) would be competitive with the PWR, i.e., about $1450 per kilowatt (1982 dollars) based on an 800 MWe size. A widely held belief among many people, however, is that the large HTGR is somewhat more expensive than the LWR and does not have comparable operating experience. The costs of the HTGR might be made more competitive if licensing requirements recognized the HTGR's intrinsic resistance to massive release of fission products.

Similar economic uncertainties face the modular HTGR. While there are no unresolved questions regarding process parameters for fail-safe design, there are large uncertainties in the design details and the fabrication and erection procedures which may lead to low costs. These uncertainties can be narrowed only through practical experience.

Economic uncertainties face the PIUS as well but even more severely because this reactor does not yet have a proof-of-principle demonstration. Will the hydraulic balance system work, or will it keep the reactor shut down most of the time? Will the thermal efficiency be as high as 30 percent? How does one maintain and repair equipment of the primary coolant system which is immersed deep in the pool of borated water?

Our first principles analysis indicates that there is hope that the PIUS may cost less than the large HTGR or even the APWR or ABWR. The major new cost of PIUS is its prestressed concrete reactor vessel (PCRV); however, the PIUS PCRV is much less complicated than the HTGR PCRV because it has fewer internal cavities. The construction of the PIUS PCRV appears to be easier and to take less time and should cost less per unit of concrete and steel.

Although a thorough licensability study needs to be made with the cooperation of the Nuclear Regulatory Commission, the basic design of the PIUS obviates the need for a separate emergency core cooling system, a dedicated residual heat removal system, a high pressure containment building, and a high reliability emergency power supply system. These systems together are estimated to have a direct cost of $275 to $360 million, or $230 to $315 per kW for a typical 1139 MWe PWR[127] (roughly equivalent to the reactor of Table 2). We believe the PIUS PCRV should cost about $150 per kW (the equivalent of $2,000 per cubic yard of materials); this is to be compared with the PCRV cost of $66 per kW ($2400 per cubic yard of materials) GCRA estimates for the 855 MWe HTGR.[128] Since the PCRV cost is expected to be well below the cost of the safety systems it more or less replaces, the chances of the PIUS being economic are reasonable.

When one compares the scope and complexity of today's 1100-1300 MWe reactors with the smaller, simpler, more easily built and operated reactors of the late 1960s and early 1970s, an obvious question is, should the industry not look harder at making tomorrow's reactors look more like yesterday's? Indeed, a recent Westinghouse study[129] now claims that its two-loop plants are competitive with larger LWRs. With the exception of ASEA-ATOM's study of the PIUS concept, the industry has not looked seriously for a design with the few basic safety functions (shutdown, primary water supply and level measurement, decay heat removal, and containment) provided in a simple and rugged way (and not necessarily satisfying all of NRC's current regulatory guides).

THE NUCLEAR FUEL CYCLE

The primary focus of the present study has been on the technology of the reactors used to generate power. However, a Second Nuclear Era cannot be carried out without consideration of the nuclear fuel. Where is it coming from? What will be done with the wastes?

This section of the report presents our views on nuclear fuel supply assurance and nuclear waste management and siting.

The Assurance of Nuclear Fuel Supply

The supply of uranium fuel for the commercial life of a power reactor has always been of concern to the owner. Most utilities enter into long-term contracts for uranium supply at a favorable price. During the early development of nuclear power, it was commonly believed that converter* reactors such as LWRs would become obsolete when low-cost uranium supplies were depleted. At present, the capital costs of new reactors have increased so much relative to fuel costs that obsolescence of LWRs no longer appears to be a threat.

There is no apparent physical limitation to the life of an LWR provided equipment is renovated or replaced as it wears out. In this respect it is similar to a hydroelectric dam, although a nuclear plant requires more extensive repair and replacement based on current experience. The plant will become obsolete only when the cost of continued operation (primarily fuel cost for a future when uranium costs are much increased) is greater than the cost of replacing it with an entirely new plant. We can envision extracting uranium commercially from low-grade sources (shales, phosphates, or sea water) for $1000 per kg or less for a very long time. At such a uranium price the fuel cost in LWRs with fuel recycle is about 2.5¢ per kWh.[130] This fuel cost compares to a "current" LWR capital cost of 4.4¢ per kWh ($1500 per kWe, 18 percent fixed charge rate, 70 percent capacity factor). The nuclear plant ought therefore to continue to be a source of cheap power and not become obsolete, provided costs of renovation remain acceptably low. When high-grade uranium resources are depleted, the reactors will continue to be provided with fuel produced in breeders or by low-grade uranium sources if necessary.

A conventional light water reactor operating with uranium fuel of low enrichment utilizes about 5600 ST (short ton) U_3O_8 (4300 tonnes U) in a 30-year life (1000 MWe, 70 percent capacity factor). If one accepts the most recent Organisation for Economic Co-Operation and Development estimate of 5×10^6 tonnes of U (assured resource at costs below $130 per kg U) in the non-Communist world,[131] that would be sufficient to fuel

---

*Converter reactor is a nuclear reactor that converts fissionable material (e.g., ^{235}U) to heat to generate steam and thence electricity. Burner reactor is another term for converter reactor. A breeder reactor is a nuclear reactor that generates new fissionable material (more than it consumes as it operates).

1160 GWe of nuclear power for 30 years. A recent careful estimate of nuclear power prospects for 1999 indicate a free world total of 410 ± 40 GWe.[132] The OECD anticipates nuclear power capacity will double or triple between 2000 and 2025.[133] Matching the low-cost uranium resources against this projected increase in nuclear power use leads us to infer that there could be a nuclear fuel supply shortage or substantial uranium price increase sometime after 2025, and probably not before.

We do not advance this argument to support a contention that breeders are not necessary. Rather, we believe that breeders will produce nuclear fuel to be consumed in converter reactors more cheaply than the equivalent of $1000 per kg U we might project for "burning the rocks." And the environmental impacts would obviously be less. The point of the argument is that we do not envision any future lack of fuel for the reactors of the First Nuclear Era or for the converter reactors of the Second Nuclear Era.

We looked briefly at the prospects for breeders, of which four types are apparent:

a. fast breeders, principally the liquid-metal fast breeder reactor (LMFBR).

b. fission-fusion hybrids.

c. accelerator-driven breeders.

d thermal breeders.

Fast breeders are on the threshold of commercial application with the advent of large prototypes in France and the USSR. The LMFBR is a promising technology for maintaining low fuel costs and moderate electricity costs in an expanding nuclear economy.[134] For scenarios with low nuclear growth, it will be necessary to bring their capital costs down for them to compete with improved converter reactors. We hope that through studies such as the ANL Rockwell effort LMFBR capital costs can be brought down to approach those of LWRs.[135]

Fission-fusion hybrids[136] are believed by some to be the most feasible embodiment of fusion technology. If so, one might envision nuclear fuel factories based on fusion neutrons. These plants might produce little or no surplus power but one might support a dozen or more converter reactors. The fuel factory would contain a complete set of fuel reprocessing, fabrication, and high-level nuclear waste treatment facilities. The choice of LMFBR versus the hybrid would clearly be based on economic and commercial feasibility, not to speak of the technical feasibility of fusion.

The "electric" breeder based on the use of neutrons produced in accelerator targets might be developed.[137] The scientific feasibility of this approach is well established and the technology of high energy, high current accelerators continues to improve. There is no evidence that this type of fuel production would be economic, but if the other breeder concepts fail, accelerator-produced fuels may be able to compete with or supplement uranium from ore.

The expected impact of more costly uranium on converter reactors would be the adoption of more efficient fuel cycles. Fuel recycle based on reprocessing would be adopted. The enrichment plant stripping of ^{235}U from tailings combined with fuel reprocessing and recycle could readily improve the fuel utilization of LWRs by a factor of 2. An additional factor of 1.3 might be gained by spectral shift control as envisaged for the Westinghouse APWR. More radical changes, such as the tight-pitch lattices investigated in the DOE light water breeder program, are possible, but the economics of these designs have not been adequately explored. Heavy-water reactors and HTGRs have historically been regarded as efficient machines for fuel recycle.

Finally, thermal breeders represent an ultimate evolution of thermal reactors. The Department of Energy has operated the Shippingport PWR with a ^{233}U-thorium core intended to demonstrate thermal breeding. We are not convinced that even for high-cost uranium it would ever be economic to breed in light-water, heavy-water, or gas-graphite reactors. However, it could well become economic to consume

10 percent of the source material (uranium plus thorium) in efficient converters, as compared to 0.6 percent in present LWRs or 60 percent plus in breeder cycles. Another potential thermal breeder system was operated successfully in the Molten Salt Reactor Experiment (1965 to 1969). This concept is based on a circulating fuel consisting of a mixture of fluoride salts and a graphite moderator. We continue to regard molten salt reactors as practical breeders should they be developed.

The breeder would be needed as a commercial entity before 2035-2050 to support rapid growth of nuclear power if fossil fuel consumption were reduced by Government edict because of environmental or national security considerations. Though this now appears unlikely, the U.S. Government and the governments of other industrial nations believe the development of renewable, ultimate energy sources is sufficiently important to justify R&D expenditures on such technologies of about $2 billion per year. This is not an unreasonable sum in relation to the current cost of the world's energy, roughly $1 trillion per year.

Nuclear weapons proliferation is a risk which must be considered in long-term planning of the nuclear fuel cycle. In general, recent United States and international studies[138,139] have concluded that diversion of weapons material from a civilian nuclear fuel cycle is not an attractive route for the production of nuclear weapons. Furthermore, continued use of the LWR fuel cycle as envisioned for the Second Nuclear Era tends to be as proliferation-resistant a choice as can be made.

From this analysis of the options for assessing adequate supply of uranium, we conclude

1. A Second Nuclear Era based on converter reactors is likely to last a very long time. R&D funds should therefore be spent to ensure that the reactors are the ones we want.

2. Breeders are unlikely to compete with LWRs for the next fifty years unless their capital costs are low. Achievement of such low capital costs should be a primary goal of breeder development.

Nuclear Waste Management and Siting

Nuclear waste management is driven by several forces, none of which supply clear guidance for immediate action. These forces are (a) the desire to demonstrate that high-level wastes can be managed permanently in an environmentally acceptable way and actually to implement a high-level waste disposal project, (b) the uncertainty about the timing and form of fuel recycle and, (c) the nuclear weapons proliferation risk of the plutonium contained in growing national stocks of spent fuel.

The passage of the Nuclear Waste Policy Act of 1982[140] represents the most important action yet taken by the United States toward resolving the waste issue. The Act provides a schedule for the siting, construction and operation of repositories that will protect the public and the environment from any hazards of high-level waste. It also establishes the federal responsibility for disposal of such waste. It defines the relationships between federal and state governments. Finally, for financing the program it establishes a superfund collected from the utilities generating nuclear power.

The implementation of the Act would demonstrate the feasibility of high-level waste disposal in a U.S. setting. We are concerned that the Act provides no clear mechanism for adjudicating a governor's veto of a site other than a Congressional override. However, the legislation contains provisions for possible substantial inducements to communities and regions for their participation. We recommend that such inducements conceived imaginatively be offered to the states and localities designated as waste disposal sites.

We are impressed with the progress being made in Sweden toward high-level waste disposal.[141] The national government is setting up facilities, in rock, for the interim storage of spent fuel for up to 60 years. At that point, the radioactivity would have decayed to a level where only minimal heating would occur in a permanent repository, also being set up by the Swedish government.

Aside from the mandated demonstration of permanent disposal of a portion of the U.S. waste, we believe that most of it should be stored for 50 to 100 years to decay. This would allow time for sorting out the reprocessing questions and for optimizing the permanent storage technology. In the interim, wastes could best be stored at the reactor sites (which are already likely to be dedicated to long-term nuclear use as discussed on pages 15, 75, 100, 101). There may be a need for some centralized interim storage facilities to be owned by the federal government, also provided for in the Nuclear Waste Policy Act.

The Institute for Energy Analysis has for a number of years advocated a nuclear siting policy which concentrates reactors into relatively few dedicated sites.[142] Concentrated siting would be safer as well as more economical than our current dispersed siting of reactors. Such a policy could be implemented in the United States by adding reactors to the existing 100-odd sites. It would confer an element of permanence to the sites and thereby open new options for waste management and reactor decommissioning. This concentrated siting policy fits well into our strategy of a Second Nuclear Era.

CHAPTER III. INSTITUTIONAL ISSUES FOR A SECOND NUCLEAR ERA

Institutional issues are covered in several papers supporting the study of a Second Nuclear Era.[143,144] The institutional considerations, however important, were not studied in sufficient depth to justify strong recommendations. We provide a brief overview of our findings in this chapter.

LICENSING AND REGULATION

A Second Nuclear Era will require regulatory stability and predictability; their absence today is one of the factors which inhibits utilities from committing to multibillion dollar nuclear investments. Efforts to produce greater regulatory stability and to streamline the licensing process have been launched repeatedly during the 1970s and 1980s. Licensing reform bills are currently before Congress. Despite support from both Democratic and Republican Administrations these efforts have not yet gained the approval of Congress.

Licensing and regulatory reform measures have not gained favor because when promoted in isolation they engender public suspicion. They might better be brought forth in association with a commitment from the nuclear industry for producing greater safety margins. Licensing reform might be feasible only if it is part of broader regulatory and safety reform.

There are a number of desirable licensing and regulatory reforms being currently proposed,[145] including the following:

1. early site review and approval
2. one-step licensing, eliminating the need for obtaining an operating license
3. state takeover of various NRC responsibilities (e.g., environmental impact assessment and determination of need for power)
4. prohibition on backfitting, except (1) at the request of the owner-operator or (2) when it can be shown by the NRC that there would be a cost-effective reduction of risk

These licensing and regulatory reforms are commonly associated with the development of standard plants. Standard plant designs could be given early generic approval. Early site approval combined with early design approval of a standard plant could substantially reduce the time between a utility's decision to build a plant and its commercial operation.

INDUSTRY AND REGULATOR

Though licensing and regulatory reforms are frequently raised in discussions of institutional or nontechnical matters, the underlying relationship between the industry and its regulator (the NRC) is not often discussed. Yet it is vital that this relationship be reassessed in any examination of a Second Nuclear Era.

Perhaps the most significant feature of the United States nuclear industry today is its fragmentation. Forty-three utilities or utility consortia own and operate commercial nuclear power units today, and it is likely that 17 more utilities will be in the nuclear business by 1990. Some of these utilities serve as their own constructors, but more frequently they contract with privately-owned architect-engineers (AEs) to design and construct the large majority of the generating facility. There are at least 12 AEs today that can perform this role. In addition, four reactor vendors provide nuclear steam supplies to the utilities. The dispersed U.S. industry contrasts sharply with the nuclear industries found in other nations. France has the most centralized nuclear industry with one nationalized utility, one nuclear steam supply vendor, and two architect-engineers. Canada's nuclear industry is also highly centralized, with most construction taking place in Ontario and under the auspices of one utility and vendor (together serving as their own architect-engineers).

The fragmentation of the U.S. nuclear industry produces two major problems. First, with a large number of organizations involved, it is exceedingly difficult to ensure a quality performance from all. Regulatory scholars have noted that regulated industries, across numerous fields of endeavor, invariably demonstrate differing degrees of managerial capability and dedication to safety. The poor performance of some can cast a shadow over an entire industry. Second, with fragmented responsibilities, no one organization acts as an overall integrator for safety. Reactor vendors supply the nuclear steam supply system; A-Es are responsible for the design and procurement of equipment for the balance of the plant; and the utilities are responsible for quality assurance and licensing. With each organization concentrating upon its own area of responsibility, work at the interface of these activities often suffers.

Recognizing these problems, and being attuned to public pressures, the Nuclear Regulatory Commission (NRC) has felt obliged to play an increasing role in the nuclear business. The NRC, realizing that an accident or inadequate safety management anywhere reflects negatively upon the utility, the technology, and the NRC itself, increasingly tries to define what safety is--in innumerable rules and regulations--and aims to enforce compliance through these standards.

The strong interventionist policy of the NRC, designed to overcome the structural weaknesses of the industry, in turn produces problems of its own. First, and perhaps most deleterious, accountability, and not responsibility, becomes the industry's operating mode. Regulators and industry officials gradually come to view conformity or compliance with the rules, rather than actual performance indicators, as the measure of safety. So much time and attention are devoted to these surrogate measures of safety ("complying with the regulations") that the larger goal of such regulation may be neglected. Industry innovation does not take place perhaps because the sense of responsibility has shifted or because industry fears that these initiatives will simply be added to (not subtracted from) the requirements that the NRC already imposes.

Second, the shift in responsibility to the regulator can have serious safety implications because a central bureaucracy, no matter how capable, cannot provide consistent regulation to a diverse and varied industry at the level of detail required by NRC standards. Diverse capabilities and circumstances require a flexible approach to safety management; a central bureaucracy by its very nature is not capable of that flexibility. Third, this mode of regulation can devastate the industry's morale and its devotion to duty. Constant oversight and punitive action in the event of noncompliance with the rules produce an unhealthy spirit of skepticism and resistance toward all regulation.

Hence, while the NRC has sought to overcome institutional weaknesses, it has also created its own problems, not the least of which is the highly adversarial relationship between it and the industry.

SELF-REGULATION

In recognition of the aforementioned problems and in response to the TMI accident, the nuclear industry itself has taken a number of positive institutional safety-related steps. These measures have already been mentioned in Chapter II. They include the establishment of internal utility safety oversight organizations, INPO, NSAC, NEIL, the Industry Degraded Core Rulemaking Program, and an increase in Nuclear Utility Task Action Committees. Because of this heightened activity, it is possible for the first time to conceive of a nuclear regulatory regime that is imposed from within (industry self-regulation) as well as from outside (the NRC). Though it is inconceivable that the NRC would be removed from its statutory duties, it is possible to envision the NRC operating in a less prescriptive (more performance-based manner) than in the past due to industry self-regulating practices.

The institutional focus for self-regulation has been INPO. INPO's efforts to bring industry performance up to a uniform and acceptable level of performance have been very promising. It is not yet possible, however, to gauge the extent to which INPO has seized the attention of all nuclear utilities. It would be unrealistic to expect NRC regulation to change or diminish significantly on the basis of INPO's efforts thus far. The onus, therefore, is on INPO to demonstrate that through its efforts effective regulation is indeed taking place and can be carried out in lieu of (not in addition to) NRC regulation.

POSSIBLE INSTITUTIONAL FUTURES

It is now recognized that a successful nuclear power reactor project requires strong management and a strong technical organization. This one observation suggests that a Second Nuclear Era would not be a simple repetition of the First Era with its proliferation of designs, vendors, architect-engineers, and utility customers. The institutions will be limited by the availability of talent. One appropriate response to significant capacity expansion would be the formation of new institutional variants such as service companies, utility-owned regional companies, or even a government-owned regional nuclear power authority. Some of these entities are already emerging.

Nuclear service companies could be individual corporations that would be employed by nuclear utilities to carry out onsite technical and managerial tasks related to the construction and operation of nuclear facilities. Utilities would retain ownership and financial and liability responsibilities but would delegate safety responsibilities in selected areas (the scope of which could run the gamut from narrow, focused jobs to full and complete responsibility). Service companies are rather commonly used at large-scale and complex government-owned facilities. No service companies, with broad safety mandates, however, have yet appeared to serve several utilities.

A more ambitious institutional undertaking would be the establishment of utility-owned regional nuclear power companies (RNPCs). These companies would be formed by a group of utilities to have complete financial, operational, licensing, and safety responsibilities pursuant to the construction and operation of nuclear power facilities. Utility ownership of RNPCs would be a further extension of the now-common practice of multi-utility ownership single utility management of existing nuclear power plants. RNPCs would generate electricity from nuclear power facilities, and parcel the electricity to its utility owners, who in turn would carry out their normal transmission and distribution tasks.

An even more radical variant of the utility-owned regional company would be a government-owned regional nuclear power authority (RNPA). These organizations would be self-financed and generate power from nuclear facilities and sell it to existing utilities for further distribution.

Institutional configurations for a Second Nuclear Era are closely related to siting policy. Concentrated reactor siting, as advocated by the Institute for Energy Analysis, would probably lead to consolidation of the utility industry into relatively few operating entities, each entity capable of handling the extremely large blocks of power produced by three or four such sites.

Operation at concentrated sites should be safer than operation at dispersed sites. However, if the reactors are already inherently safe, as might be the case in a Second Nuclear Era based on inherently safe reactors, then the advantages of site concentration are less pressing. Thus we concede that the incentive to concentrate sites, just as the incentive to consolidate utilities, in some measure depends on the technology available.

CHAPTER IV. SUMMARY, RECOMMENDATIONS, AND OBSERVATIONS

SUMMARY OF FINDINGS

This study sought first of all to determine whether there exist plausible concepts for intrinsically safe reactors. As a prelude to this investigation, we examined the safety of today's reactors, especially in the light of the lessons learned from the Three Mile Island-2 accident. Further, since a resurgence of nuclear energy demands that reactors be cost-competitive, we studied the economics of nuclear power today and in a Second Nuclear Era based on reactors that are more forgiving than are today's reactors.

Regulatory and other institutional improvements, though not central to this largely technologically-oriented study, were given some attention, as were fuel assurance, waste disposal, and siting.

In this section we summarize our findings on each of these matters.

The Safety of Current Reactors

If we measure the safety of reactors by the median probability of a core melt as revealed by PRA, then we must conclude that every one of the commercially available reactors--LWR, BWR, CANDU, and HTGR--is quite safe--i.e., its median core-melt probability is not higher than the proposed NRC safety goal, 10^{-4} per reactor-year. We found that the core-melt probability for LWRs is on average about three- to sixfold lower today than it was before Three Mile Island because of voluntary and Nuclear Regulatory Commission-mandated changes carried out after Three Mile Island (TMI). This improvement more than compensates for the pre-TMI core-melt probabilities being higher than the median of Rasmussen's range. In addition, estimates of the source term have been reduced considerably for most accidents (by a factor of about 20), and better evacuation planning may be counted upon to reduce the consequences estimated in WASH-1400 perhaps by another factor of 2. Thus, application of the methods used in WASH-1400 suggest the likelihood of a large release that causes many casualties from post-TMI LWRs are at least an order of magnitude, and perhaps two ~~orders of~~ magnitude lower than were predicted in WASH-1400. In any case, most post-TMI LWRs seem to have median core-melt probabilities that are below 10^{-4} per reactor-year.

Are Current Reactors Safe Enough?

We have accepted, somewhat arbitrarily, NRC's proposed safety goal of a core-melt probability of 10^{-4} per reactor-year. In a 500-reactor world, this implies one core melt (worldwide) per 20 years on the average.

As our work progressed, we came to realize that we must distinguish more clearly between the current period that ends with the century, when the total number of power reactors in the world will be close to 500, and the period of the Second Nuclear Era (20 to 50 years later) when the world's reactors may number several times or even 10 times more. The latter contingency may seem remote now; but if the CO_2 or even acid rain issues become urgent within the next 20 years, pressure to move to heavy dependence upon nuclear energy might become very strong. Thus the core melt probability of 10^{-4} per reactor year, which we accepted as a reasonable goal in a 500-reactor world, is almost surely insufficient in a world with many more reactors.

Studies of advanced PWRs and BWRs and the Sizewell-B concept indicate that light water reactors (with capital costs 20 percent higher than that of present plants) should achieve a 10^{-5} per reactor-year core-melt probability. This should make them useful in a Second Nuclear Era even if there is a large expansion of nuclear capacity. We also suggest that a core-melt probability of 10^{-5} per reactor year could be used as a safety goal for a Second Nuclear Era.

Comparison of Existing Reactor Types

We have not tried to compare PRAs for the different types of commercial reactors. The non-uniform basis and quality of existing PRAs makes a detailed comparison all but impossible. Nevertheless, our impression based on the data available to us (for LWR, CANDU, and HTGR) is that there is little difference between LWR and CANDU, but HTGR shows distinctly lower consequences for accidents that in light water reactors might cause offsite releases. On the other hand, HTGRs seem to have about the same probability of loss of the plant as do LWRs.

Prospects for Inherently Safe Reactors

Despite our finding that existing reactor types as judged by PRA are adequately safe for wide deployment in a Second Nuclear Era, we believe any such estimates will always be subject to considerable uncertainty. We therefore believe it very desirable to develop reactors whose safety is inherent and manifest and does not depend on intervention of devices each of which has some probability of failing or on operator skills and good judgment which could vary considerably.

The Process Inherent Ultimately Safe reactor proposed by ASEA/ATOM appears to be inherently safe—i.e., no sequence has been identified that would lead to a core melt. Moreover, PIUS seems to be highly resistant to acts of sabotage or war and to be particularly forgiving of inadvertency on the part of the operator. If PIUS could be built as cheaply as an LWR, and if it could be operated conveniently and reliably, then it could be a means for restoring confidence, as well as increasing utility interest, in nuclear power.

While PIUS is a unique concept, we expect that it is not the only possibility for an inherently safe reactor. The fail-safe nature of small modular gas-cooled reactors has been demonstrated at the AVR in West Germany. Various pool-type breeder concepts and molten salt reactors may be inherently safe as well. The PIUS concept is recommended here because, of the inherently safe choices, it takes advantage of well-understood light water reactor technology and has the best known protection against sabotage and acts of war. Nevertheless the other systems, notably the modular HTGR, are also recommended for serious examination.

Costs

There will be no Second Nuclear Era unless the costs of nuclear power are kept under control. Perhaps as important as the absolute capital cost of reactors is predictability of capital costs: unless the cost of a new plant can be judged reliably before construction begins, few nuclear plants are likely to be ordered.

The cost of nuclear power from the plants currently in operation is low, provided average or better plant availability is achieved. By current standards, the initial investment in these plants was a bargain, and even if the order of $150 per kW has been spent on each unit for backfitting, the plants are still very competitive with fossil plants.

The plants currently under construction have expected costs varying from about $1100 per kW, to $3500 per kW or more (in 1983 $). At the low end of the scale nuclear power is competitive with coal; at the high end of the scale nuclear power is unattractive.

The increased cost of nuclear plants is attributed to many mutually reinforcing factors: increased materials and labor costs resulting from regulatory pressures, poor labor productivity, higher interest rates, extended construction schedules, and general inflation. In a Second Nuclear Era it should be possible to improve at least some of these factors: reduced labor content through standard designs and reduced interest and escalation through improved construction schedules. In the case of inherently safe reactors, the balance-of-plant costs should be reduced significantly by use of standard commercial equipment and construction practices; this would compensate for any increased cost of the nuclear steam supply.

Reactor Regulation

The cost of nuclear plants is sensitive to their regulation. Only if requirements imposed by NRC do not change during construction are firm estimates of capital cost possible. Thus a Second Nuclear Era will require regulatory procedures that are stable.

We are not prepared to say whether the incrementally improved LWRs can be proven in advance to have no deficiencies that would be revealed after construction has begun. Were such deficiencies to be found, expensive and unexpected backfits might be required. On the other hand, the improved LWRs, meeting as they do stringent safety criteria, ought to be less liable to expensive backfits than are existing reactors. We would hope that NRC, in promulgating its regulations, will take full account of the improvements being incorporated in newer LWRs.

If reactors are indeed becoming as safe as PRAs predict and since utilities are increasing their competence, we find the NRC's present approach to regulation becoming unnecessarily burdensome. We believe a more performance-based approach to regulation will lead to safer, more operable plants and better relationships between NRC and the utilities.

Should inherently safe reactors become commercial, we would expect the regulatory burden for those plants to become far less than it now is. Perhaps more accurately, such concepts can become competitive only if their inherent safety were recognized by NRC and resulted in a relaxation of prescriptive regulatory restrictions as compared to those imposed upon reactors that depend on active safety systems.

Assurance of Fuel Supply, Waste Disposal, and Siting

Assurance of fuel supply, waste disposal, and siting, though not directly affecting safety of reactors, nevertheless is central to the long-term future of nuclear energy. Though we have devoted relatively little study to these issues, we offer the following observations with regard to them.

Assurance of fuel supply. When breeders were first proposed, reactor capacity was expected to expand rapidly, and this was expected to exhaust the known uranium resources. Rapid development and commercialization of the breeder appeared to be the only way to assure fuel for a rapidly expanding nuclear industry.

Considerable worldwide progress has been made in breeder technology and commercial-scale prototypes will soon be in operation. The capital costs of breeders have thus far been too high to support immediate widespread deployment. Moreover, the slower-than-anticipated growth of nuclear capacity has provided time for emergence of other alternatives, including the following:

1. more efficient use of uranium in converter reactors
2. uranium from sea water and other low-grade sources
3. fission-fusion hybrids
4. accelerator-driven breeders

Alternative (1), the high gain converter, has always been an option but does not provide an essentially inexhaustible energy source.

Though enthusiasm for fission-fusion hybrids and for uranium from sea water run high in some quarters, we consider a shift in emphasis away from the breeder in favor of these still speculative possibilities to be unjustified. With respect to fission-fusion hybrids, we believe the proper time to initiate major efforts is after, not before, a plasma usable in a fission-fusion hybrid has been demonstrated. With respect to uranium from sea water, we remain skeptical of the claims that the sea can yield an essentially inexhaustible supply of uranium at less than $200 per pound of U_3O_8. The large Japanese pilot plant for recovery of uranium from sea water is scheduled to operate by the mid-1980s.[146] At that time a reassessment of the prospects for uranium from the sea is indicated.

We have been unable to find a basis for enthusiasm over the economics of the accelerator breeder and therefore find no basis for development at this time. Nevertheless, it cannot be ruled out as a long-term option.

Since nuclear energy worldwide is growing slowly, the pressure for greatly extending the fuel supply has relaxed. Nevertheless, we recognize that incentives to deploy reactors rapidly could develop again, and therefore assurance of fuel supply could once more become a pressing concern. We therefore recommend

1. continuing development of breeders,
2. continuing development of more efficient converter fuel cycles,
3. continuing assessment of the fission-fusion hybrid, the accelerator breeder, and extraction of uranium from the sea.

Waste disposal and siting. The passage of the Nuclear Waste Policy Act of 1982 represents the most important action ever taken by the federal government toward resolving the waste disposal issue. The 1 mil per kWh assessment on users of nuclear power will yield about $300 million per year (increasing to some $600 million by the 1990s) for waste disposal and should go far toward ensuring serious, adequately funded attention to waste disposal.

We believe that irradiated nuclear fuel should continue to be stored for a long time (50 to 100 years) at the reactor site to reduce the risks of fuel transportation and of potential overheating of the rocks surrounding the nuclear waste repository. In effect, we would be dedicating the reactor sites to more or less permanent use by the nuclear industry. Though we mention this siting policy in the context of storage of spent fuel, we point out that the longevity of these sites implied by this strategy makes these sites well suited for accommodating additional reactors. We point out that multi-reactor sites are the rule rather than the exception almost everywhere, except in the United States. We would encourage such siting policy for the United States in a Second Nuclear Era.

We are concerned that the Nuclear Waste Policy Act provides no clear mechanism for adjudicating a governor's veto of a site other than a Congressional override. To avoid such confrontation, we recommend that imaginative inducements, including liberal financial ones, be offered to states and localities designated as waste-disposal sites. The exact nature of such inducements would have to be worked out by the managers of the Federal Radioactive Waste Disposal Program. We urge that this matter be given priority so that the federal government is not forced to initiate poorly analyzed remedies should it be confronted with a governor's veto of a proposed waste disposal site.

RECOMMENDATIONS

Based on the findings just summarized, we have come to two main conclusions and recommendations:

1. That incrementally-improved, post-TMI light water reactors pose very low risks to the public even in a world with several times as many reactors as are now operating. However, investor risk and high and uncertain capital cost may limit their market.

2. The development of a Process Inherent Ultimately Safe (PIUS) reactor or other inherently safe concept should be undertaken to provide a technological alternative with intrinsic safety as an option for widespread deployment in the future. If preliminary development of the system continues to show promise, a prototype of such a reactor should be built to better determine its operability and economics and to prove its safety characteristics.

The development of very safe reactors is already taking place with the development of ABWR, APWR, and Sizewell B. Thus an LWR adequate for a Second Nuclear Era ought to be available well before the year 2000. If the incrementally improved LWR is to be the only option available for a Second Nuclear Era, there may be little that government or the nuclear enterprise need do beyond what is now being done.

We are unconvinced that such a laissez-faire approach provides an adequate range of options or is an optimal course for extensive deployment of reactors in a world where there is extensive concern about the safety of nuclear plants. With acid rain and CO_2 continuing to accumulate and with the other non-fossil sources of electricity beset with uncertainties, we believe it necessary to consider what more could be done to ensure a successful Second Nuclear Era. We therefore offer the following observations both on the design of the Second Nuclear Era and on measures to be taken by the various actors to ensure a successful Second Nuclear Era.

Our considerations are largely confined to the United States; yet because the United States is so well-endowed with coal, the case for nuclear energy is not as strong here as it is in much of the rest of the world. As of this writing, more nuclear power is being generated outside than inside the United States. Moreover, the capacity factors of reactors in a number of European countries, as well as in Canada, are significantly higher than in the United States. These trends augur a future in which the United States becomes a bystander in nuclear energy. Thus a Second Nuclear Era may, in countries such as France or Japan or the Soviet Union, simply be a continuation of the current era; whereas in Sweden, the United States, and the Netherlands, a Second Nuclear Era may require more positive public perceptions of nuclear energy.

An Inherently Safe Prototype Reactor Should be Built

We urge development of PIUS or an equivalent inherently safe concept, possibly a modular HTGR, to a stage where its practicality can be determined. This would require a prototype--say, 100 MWe. Such an undertaking might be international, and we can envisage private sources providing some of the funds.

We are not unmindful that this recommendation could be interpreted to imply that we do not believe current reactors are safe enough. On the contrary, we are convinced that existing, post-TMI reactors pose low risks to the public. We believe, too, that evolutionary changes to LWRs could make them safer still. However, the evolutionary changes to LWRs have tended to improve safety at the expense of greater complexity and cost. We believe that a reactor that derives safety from simple features that are inherent in the system could profoundly increase the acceptability of nuclear energy.

The considerations that justify the government's pursuing inexhaustible long-term energy sources for possible deployment 20 or even 50 years from now, also justify development of PIUS for possible deployment in a world where a forgiving reactor may find a large market and increase the usefulness of the nuclear option. The safety of the PIUS reactor is transparent and relies on the inherent design, in contrast to the safety of conventional reactors which require elaborate safety systems. It should therefore be possible to design a relatively simple and, we hope, a cheap reactor. Being smaller than conventional LWRs, a smaller investment would be committed per unit. The risk of losing the investment or not being able to complete the plant would be small. The technical expertise and security force required to operate the plant safely would be much less than for a conventional LWR. Finally, the availability of a forgiving reactor may contribute to public acceptance of nuclear power.

We would estimate that to develop and then build a 100 megawatt PIUS reactor might cost $500 million and might require 10 to 12 years from the time the project started. Such a project would be carried out in stages. The first stage would involve conceptual studies with the intent of selecting the best inherently safe concept. The second stage would involve system and hardware development to prove the underlying principle to be sound. The final, and most expensive stage would include the detail design, licensing, and construction of the reactor.

Would demonstration of PIUS compromise the existing reactor industry? We do not believe this to be a realistic concern now, since there is so little prospect for new reactors in the United States at present. Should PIUS turn out to be cheap, as well as inherently safe, it would undoubtedly become an opportunity for, as well as a challenge to existing reactor manufacturers. The skepticism of some reactor vendors does not in itself constitute sufficient reason for ignoring PIUS.

A demonstration of PIUS would be a necessary step in proving both technical and commercial feasibility of the concept. A prototype of the modular HTGR would also be necessary as a step toward commercialization and to demonstrate its inherent safety.

PLANS FOR A SECOND NUCLEAR ERA

In this section we visualize a plausible institutional framework for the Second Nuclear Era, and offer some observations on how the transition to this era may be achieved. We assume, based on our previous findings, that both inherently safe and improved LWRs will be available within the next 15 years.

Time Horizon

The depressed demand for new nuclear power plants makes it unlikely that there would be many new orders before the 1990s. Considering the time lag for plant construction, we then get to the turn of the millenium before new plants are in operation. If there is to be a Second Nuclear Era in the United States, a convenient target date is the year 2001.

If current projections of continued but slow energy growth are correct, the United States would require on the order of 500 GWe of nuclear capacity in the first half of the 21st century. The ultimate capacity might be greater if fossil fuels are to be phased out of base-load electricity generation or if the trend toward electrification continues to be strong.

The converter reactor technology to be deployed will have a long useful life, especially if efficient fuel recycle technology is developed. Depending on the ultimate uranium resources, breeder technology would be phased in to maintain fuel supply.

Leadership

The original leadership for nuclear power came from the Joint Committee on Atomic Energy and its agency, the Atomic Energy Commission. The industry developed with the incentive provided; however, the political encumbrances of nuclear power have hindered the private sector from taking over leadership in the same sense that it leads the oil business.

Since the demise of the Joint Committee and the split-up of the AEC, leadership has been widely diffused, but the NRC appears to have more than its share of the initiative with the industry in a reactive mode. The absence of positive leadership has allowed the technology to drift into an uneconomic mode--turning off the future growth of the industry.

In an ideal world, the utility industry itself would take all the necessary measures to preserve the nuclear option as one of the two major generation technologies it needs. In a practical sense, that industry is too fragmented and in too weak a financial position to undertake such a long-term commitment.

We believe the utilities should be held accountable for a more limited, but still vitally important role. We are referring to their prime responsibility for safe and economical operation of their plants. We believe they should accept more responsibility for strengthening their management and technical capabilities, for initiating desirable improvements to their plants, and in supporting the efforts of the reactor manufacturers to develop better products. The industry should motivate the federal government to adopt policies conducive to the expansion of electric power facilities generally and nuclear power in particular.

If the government wishes to preserve a nuclear option, it needs to create leadership within the government to balance the regulatory mandate of NRC. There is currently no government agency that dares to be innovative or to promote nuclear energy. Without such initiative by the government, the current de facto moratorium is likely to continue. The logical agency to provide leadership is DOE, reinforced by friendly committees in Congress.

Reactor Technology

Given favorable operation of the present plants, continued use of conventional LWRs is likely; the newer ABWRs and APWRs would involve a lower risk than present reactors, even in a world containing many more reactors than now exist. Nevertheless, we consider reactors that are as forgiving as PIUS, or possibly the modular HTGR, provided they are economical and practical, to be even more desirable than are the incrementally improved LWRs represented by ABWR and APWR.

The most important goal during the next decade is good operation of the existing power reactors; we cannot stress too strongly the importance of avoiding another TMI-like episode. With post-TMI improvements in place, a core melt during the next 20 years is unlikely, at least as judged by PRA. Nevertheless, we believe certain changes in the organizations and policies responsible for nuclear energy are desirable. They are as follows:

Regulation

NRC's role must be defined in relation to the inherent safety of reactors: the greater the inherent safety, the smaller is NRC's role. This central principle will have to be recognized if the advantages of inherently safe reactors are to be realized. Nevertheless, the NRC should continue to be the center of regulation in the United States; however, greater use should be made of incentives for self-regulation by industry organizations. For example, INPO should be allowed an expanded role in operator training and qualification, and its venture into construction auditing should be encouraged. No one has more to gain from safe, efficient operation and sound construction management than the owners of the plants. The insurance underwriters are another potential source of self-regulation by the industry.

The licensing of new plants generally of standard designs, should be "one stop." The requirements should include, but not be limited to, satisfaction of safety goals. Once a license is granted, only cost-effective backfits should be allowed.

States or regional organizations should have a major role in determination of the need for power and siting.

Siting

It should be possible to get pre-approval of sites for standard plants. In general, reactors should be located in clusters on land permanently dedicated to nuclear power. Low-level wastes and spent fuel should be stored onsite for long periods of time. Most of the reactors for the Second Nuclear Era could be placed on existing sites. The relatively few new sites that may be required should be selected to minimize risk to the general public as judged by PRA; however, safety goal criteria should be used to balance expenditures on risk reduction against other economic requirements.

The Industry

One cannot but envy the utility organization in France, England, or Ontario: in each instance a single powerful utility manages as many as 60 reactors, most of the reactors being identical. The opportunity for learning rapidly by transfer of information from one station to another is obviously very great.

Were the United States utilities organized along these lines, with very few generating entities, each operating many reactors of standard type, we would be more comfortable with the prospects for a trouble-free Second Nuclear Era. Unfortunately, the utility industry in the United States is fragmented and is likely to remain so for the next 20 years. What integration it possesses must be imposed by entities such as INPO, NSAC, and owners' groups that lie outside the regular utility framework.

Should continuation of the nuclear industry be based on large LWRs, we believe the marketplace is likely to limit new projects to utilities with demonstrated capability to manage reactor financing, construction, and operation. The government should encourage such consolidation. We hope that eventually in the Second Nuclear Era there will be no more than 20 companies generating nuclear power. If the total nuclear capability of the United States reaches 500 GWe, each company might generate 25 MWe--less than half of the nuclear power Electricite de France will be generating by the end of the decade.

On the other hand, a more diverse structure would be possible should an inherently safe reactor become available. There is no reason that the

LWRs and the PIUS reactors could not compete, with the strong utilities having a wider choice of product.

Standard reactor designs would be developed principally by the reactor vendors based on owner-operator criteria and with architect-engineering support. Responsibility for construction management would be the utilities', who may choose to contract with a vendor for erection of a standard plant. However, the role of the architect-engineer would be reduced in that many identical plants would be built from one set of plans.

The industry would be supported by fuel cycle service vendors, EPRI (R&D), INPO (operations and construction standards), other technical service companies, and by an insurance pool. The amount of insurance available should equitably apportion the costs of a core-melt accident within the industry (without having to go to the politicians for contributions, as at TMI-2).

Fuel Assurance

Fuel assurance for the initial decades of the Second Nuclear Era is not a major concern. Spent fuel is stored onsite. If it is economic to reprocess fuel, some reactors might be dedicated to fuel recycle using high conversion fuel configurations. High-level waste from the reprocessing plants is placed into government-operated waste repositories.

Depending on fuel supply prospects, breeder technology would be developed and demonstrated in an international framework.

THE FUTURE OUTLOOK

This study has indicated a direction that, if taken, we believe will contribute to the success of a Second Nuclear Era in the United States. Overall leadership must come from the government. The various government agencies and the nuclear industry must work together to create the technology and the institutions. This will take time, but fortunately the current de facto nuclear moratorium gives us some time. We hope it will be used wisely.

REFERENCES

1. Energy Information Administration. 1983. Monthly Energy Review, DOE/EIA-0035(83/06) June, p. 80.

2. Ibid.

3. Nuclear News. 1983. "World List of Nuclear Power Plants," August 1983, pp. 83-102.

4. Institute for Energy Analysis, Oak Ridge Associated Universities. 1979. Economic and Environmental Implications of a U.S. Nuclear Moratorium 1985-2010, Second Edition. Cambridge, MA: MIT Press.

5. David Lilienthal. 1980. Atomic Energy, A New Start. New York: Harper-Row.

6. M.J. Ohanian, ed. 1977. An Acceptable Future Nuclear Energy System, Condensed Workshop Proceedings, ORAU/IEA(R)77-26, Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

7. M.W. Firebaugh and M.J. Ohanian, eds. 1980. An Acceptable Future Nuclear Energy System, Condensed Workshop Proceedings, ORAU/IEA-80-3(P), Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

8. M.W. Firebaugh, ed. 1980. Acceptable Nuclear Futures: The Second Era, Minutes from Workshop, ORAU/IEA-80-11(P), Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

9. Nuclear News. pp. 83-102.

10. Ibid.

11. A.P. Fraas. 1983. Survey and Assessment of the Technological Options Available to the Nuclear Industry in the 1980 to 2000 Period. Working Paper prepared for the Office of Technology Assessment, Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

12. Westinghouse Electric Corporation. 1971. Systems Summary of a Westinghouse PWR Nuclear Power Plant. Pittsburgh, Pa.

13. U.S. Nuclear Regulatory Commission. 1973. "Acceptable Criteria for Emergency Core Cooling Systems for Light Water-Cooled Nuclear Power Reactors," 10 CFR Part 50, Appendix A (Docket No. RM-50-1). Washington, D.C.

14. M.L. Myers, Private Communication. October 11, 1983.

15. D. Phung. 1983. *Economics of Nuclear Power: Past Record, Present Trends, and Future Prospects*, ORAU/IEA-83-13(M), Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

16. Ibid, p. 5.

17. William L. Rankin, et al. 1981. "Nuclear Power and the Public: An Update of Collected Survey Research of Nuclear Power," Battelle Memorial Institute, Human Affairs Research Center, Seattle, Washington, December.

18. U.S. Nuclear Regulatory Commission. 1981. *A Survey by Senior NRC Management to Obtain Viewpoints on the Safety Impact of Regulatory Activities from Representative Utilities Operating and Constructing Nuclear Power Plants*, NUREG-0839, August. Washington, D.C.

19. L. Martel, L. Minnick, and S. Levey. 1982. *Summary of Discussions with Utilities and Resulting Conclusions, EPRI (RP 1585)*. Palo Alto, California: Electric Power Research Institute.

20. Energy Information Administration, p. 71.

21. U.S. Atomic Energy Commission. 1962. *Civilian Nuclear Power—A Report to the President*. Washington, D.C.

22. Phung. "Economics of Nuclear Power," pp. 4, 5.

23. Energy Information Administration, p. 80.

24. Atomic Industrial Forum. 1982. INFO 168, September.

25. Energy Information Administration, p. 4.

26. Ibid, p. 70.

27. *Nuclear News*, pp. 98-101.

28. U.S. Congress (97th). 1983. "Nuclear Waste Policy Act of 1982," Public Law 97-425. Washington, D.C.

29. Energy Information Administration, p. 70.

30. K. Hannerz. 1983. *Towards Intrinsically Safe Light Water Reactors*, ORAU/IEA-83-2(M)-Rev. Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

31. A.J. Goodjohn, et al. 1983. *The HTGR--An Assessment of Safety and Investment Risk*, GA-C16928. Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

32. G.H. Lohnert and R. Reutler. 1983. "The Modular High Temperature Reactor," *Nuclear Technology* *62*:22-30. July.

33. Goodjohn.

34. E. Siddall. 1983. *The CANDU-PHW Reactor in Relation to a Second Nuclear Era*, ORAU/IEA-83-11(M). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

35. J.N. Barkenbus. 1983. *Prospects and Opportunities for Nuclear Power Regulatory Reform*, ORAU/IEA-83-5(M). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

36. J.N. Barkenbus. 1983. *An Assessment of Institutional Alternatives for Nuclear Power*. Working paper prepared for the Office of Technology Assessment. Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

37. Union Electric Co. 1979. *Preliminary Safety Analysis Report: SNUPPS*, (Calloway 1) Docket 50-483.

38. D.L. Phung. 1983. *Assessment of Light Water Reactor Safety Since the Three Mile Island Accident*, ORAU/IEA-84-2(M). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

39. R.R. Mathews. 1982. *Current CEGB Safety Policy and Criteria*, International Conference on Nuclear Power Experience, IAEA-CN42/126, International Atomic Energy Agency, Vienna, September 13-17.

40. Westinghouse Electric Corporation. 1982. *Sizewell B Probabilistic Safety Study*," WCAP-9991, Rev. 1, Vols. 1, 2, and 3. Pittsburgh, Pennsylvania.

41. Phung. "Assessment Since TMI," pp. 57-59.

42. Fraas, p. 3.

43. Ibid, p. 7.

44. F. Bevilacqua and J.L. Van Fleet. 1981. "Design Features of System 80 Nuclear Steam Supply System," TIS 7040, Combustion Engineering, Inc., Presented at American Nuclear Society Nuclear Technology Exhibit, October 23-31, Beijing, People's Republic of China.

45. Fraas, p. 3.

46. Ibid, p. 3.

47. Ibid, p. 13.

48. Ibid.

49. Phung, "Assessment Since TMI."

50. K. Paulsen, Private Communication, December 21, 1983.

51. Westinghouse Electric Corporation. 1982. Westinghouse's New 2-Loop Nuclear Power Plant, Draft Report, Water Reactor Division, Pittsburgh, Pennsylvania.

52. Babcock and Wilcox. 1983. "400-MWe Consolidated Nuclear Steam System (CNSS)--1255 MWt CNSS Design/Cost Update," BAW-1754, work performed for Oak Ridge National Laboratory, ORNL/Sub/82-17456/1, July. Oak Ridge, Tennessee: Oak Ridge National Laboratory.

53. Martel et al., pp. A-6, A-7.

54. D.R. Wilkins et al. 1980. A Post-TMI Look at Boiling-Water Reactor Plant Protection, Proceedings of IAEA Conference on Current Nuclear Power Plant Safety Issues, Stockholm, Sweden, October 20-24, pp. 103-120.

55. General Electric. 1975. BWR-6 Standard Safety Analysis Report. 50-531, February 13.

56. Ibid.

57. D.R. Wilkins. 1982. Advanced Boiling Water Reactor, General Electric unpublished document, August, San Jose, California.

58. L.R. Quarles. 1983. "Nuclear Station Achievement 1983," Nuclear Engineering International, July, pp. 15-16.

59. Siddall.

60. Nuclear News, pp. 83-90.

61. C.E. Till and Y.I. Chang. 1981. "Heavy Water Reactors: Some U.S. Perspectives," Proceedings of the Annual Meeting of the American Association for the Advancement of Science, Toronto, Canada, January 3-8, AAAS, Washington, D.C.

62. Siddall.

63. Combustion Engineering, Inc. 1979. Conceptual Design of a Large HWR for U.S. Siting, work performed for U.S. Department of Energy, Vol. 1-4, CEND-379, September. Washington, D.C.

64. Electric Power Research Institute. 1977. "Study of the Development Status and Operational Features of Heavy Water Reactors," General Electric Co., EPRI NP-365, February. Palo Alto, California.

65. General Atomic. 1982. HTGR Steam Cycle-Cogeneration Lead Plant Design and Cost Report, work performed for U.S. Department of Energy, PC 0000040, GA Project 6654, July. Washington, D.C.

66. Fraas, p. 3.

67. Goodjohn, Section 1, p. 7.

68. Phung, "Economics of Nuclear Power," p. 25.

69. Fraas, p. 32.

70. Goodjohn.

71. Lohnert and Reutler.

72. S. Untermyer. 1959. Large Natural Circulation Reactors, General Electric Atomic Power Equipment Department, GEAP-32 (Class II), September 28. San Jose, California.

73. S.N. Tower. 1982. Letter to A.P. Fraas describing a Deep Well Reactor Concept, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania. November 4.

74. E. Lantz. 1980. "Inherently Safe Nuclear Power Plants," Letter to the Editor, Nuclear Safety 21, 1, (Jan.-Feb.):25.

75. Rockwell International and Argonne National Laboratory. 1983. "Large LMFBR Pool Plant," presentation of Energy Systems Group, May 27.

76. Adolph Birkhofer. 1982. "The Use of PRA for Safety Evaluation," *Proceedings of International Meeting on Thermal Nuclear Reactor Safety*, NUREG-CP0027, Chicago, Illinois, August 29-September 2.

77. M.A. Schultz and M.C. Edlund. 1982. *The Case for an Indestructible Reactor*, Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

78. E. Teller. in David Okrent, *Nuclear Reactor Safety, On the History of the Regulatory Process*, University of Wisconsin Press, 1981, Madison, Wisconsin.

79. Willard F. Libby. 1956. Letter to Senator Bourke Hickenlooper. (Reprinted in David Okrent, *Nuclear Reactor Safety, On the History of the Regulatory Process*. Madison, Wisconsin: University of Wisconsin Press, 1981.

80. Code of Federal Regulations, Title 10, Part 50 (10 CFR 50).

81. Ibid.

82. D.L. Phung. 1983. *Review of Light Water Reactor Safety Through the Three Mile Island Accident*. ORAU/IEA-84-3(M). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

83. Tennessee Valley Authority. 1971. *Preliminary Safety Analysis Report*, (Brown's Ferry) (General Electric), Docket 50-259.

84. Portland General Electric. 1982. *Preliminary Safety Analysis Report* (Trojan) Docket 50-344, Update.

85. Consumers Power Company. 1968. *Preliminary Safety Analysis Report* (Palisades) (Combustion Engineering) Docket 50-255.

86. Tennessee Valley Authority. 1978. *Preliminary Safety Analysis Report* (Bellefonte) (Babcock and Wilcox) Docket 50-438.

87. J.W. Minarick and C.A. Kukielka. 1982. *Precursors to Potential Severe Core Damage Accidents: 1969-1979, A Status Report*, ORNL/NSIC-182 and NUREG/CR-2797. Oak Ridge, Tennessee: Oak Ridge National Laboratory.

88. Institute of Nuclear Power Operations; Nuclear Safety Analysis Center. 1980. *Analysis and Evaluation of the Crystal River 3 Incident*. INPO-1; NSAC-1, March. Atlanta, Georgia.

89. U.S. Nuclear Regulatory Commission. 1980. Annual Report. Washington, D.C., pp. 88-90.

90. Institute of Nuclear Power Operations. 1982. Analysis of Steam Generator Tube Rupture Events at Oconee and Ginna, INPO 82-02, November 1982. Atlanta, Georgia.

91. Inside NRC. 1983. "Failure of Salem 1 to Scram Lends Urgency to--But Will Slow--ATWS Rule," 5(5), March 7.

92. Code of Federal Regulations, Title 10, Part 50, Appendix R.

93. Atomic Energy Commission. 1957. Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants, WASH-740. Washington, D.C.

94. U.S. Nuclear Regulatory Commission. 1975. An Assessment of Accident Risk in U.S. Commercial Nuclear Plants, WASH-1400 (NUREG-75/014). Washington, D.C.

95. F.L. Leverenz and R.C. Erdmann. 1975. Critique of WASH-1400, Report prepared for Electric Power Research Institute, Science Applications, Inc., EPRI 217-2-3, June. Palo Alto, California.

96. Henry W. Kendall et al. 1977. The Risks of Nuclear Power Plants: A Review of the NRC Reactor Safety Study, Cambridge, Massachusetts: Union of Concerned Scientists.

97. H.W. Lewis et al. 1975. "Report to the American Physical Society by the Study Group on Light Water Reactor Safety, Reviews of Modern Physics, Vol. 47, Supp. 1, September.

98. J.G. Kemeny et al. 1979. Report of the President's Commission on the Accident at Three Mile Island. U.S. Government Printing Office, Washington, D.C.

99. Mitchell Rogovin et al. 1980. Three Mile Island, A Report to the Commissioners and to the Public, NRC Special Inquiry Group, January. Washington, D.C.

100. Institute of Nuclear Power Operations Annual Report. 1981. Atlanta, Georgia.

101. John Higgins. Nuclear Insurance Newsletter. February 1983.

102. E.L. Zebroski. 1982. "The Dynamics of Institutional Changes Following the TMI Accident," Progress in Nuclear Energy 10:

103. I. Spiewak. 1983. "An Investigation of the Nuclear Source Term," ORAU/IEA-84-5(M). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

104. Ibid, p. 18.

105. Phung, "Assessment Since TMI."

106. Minarick and Kukielka.

107. Power Authority of the State of New York and Consolidated Edison Company. 1982. *Indian Point Probabilistic Safety Study*, Vols. 1-12. New York, N.Y.

108. Philadelphia Electric Company. 1982. *Limerick Generating Station Probabilistic Risk Assessment*, Vols. 1 and 2, June. Philadelphia, Pennsylvania.

109. Peter Groer. 1983. Private Communication. Institute for Energy Analysis, Oak Ridge Associated Universities, Oak Ridge, Tennessee.

110. Tennessee Valley Authority. 1981; 1982. Annual Reports. Knoxville, Tennessee.

111. Gordon R. Corey. 1981. "An Economic Comparison of Nuclear, Coal, and Oil-Fired Electric Generation in the Chicago Area," *Ann. Rev. Energy* *6*:417-443.

112. Phung, "Economics of Nuclear Power," p.4.

113. Ibid, p. 6.

114. Quarles, p. 37.

115. Phung, "Economics of Nuclear Power," p. 6.

116. National Electric Reliability Council. 1982. *The National Electric Reliability Council Equipment Availability--Composite Unit Summary*, SR-82-99, prepared for Energy Information Administration, U.S. Department of Energy. Washington, D.C.

117. *Nuclear News*, pp. 97-101.

118. *Nucleonics Week*. September 15, 1983.

119. *Nuclear News*, pp. 97-101.

120. Atomic Industrial Forum, Inc. 1983. "The New Reality: Update on Nuclear Plant Safety," March. Washington, D.C.

121. National Economic Research Associates, Inc. 1983. Report on Edison Electric Institute Study of Impacts of S. 768, "Impacts of the Bill on Acid Rain," Committee on Environment and Public Works, EEI News Release, June 28. Washington, D.C.

122. Energy Information Administration. 1982. *Projected Costs of Electricity from Nuclear and Coal-Fired Power Plants*, DOE/EIA-03561, August. Washington, D.C.

123. J.G. Asbury et al. 1982. *A Case Study of Rate of Return Regulatory Policy Alternatives for Electric Utilities*, ANL/EES-TM-198, Argonne National Laboratory, August. Argonne, Illinois.

124. U.S. Department of Energy, Office of Policy, Planning, and Analysis. 1983. *The Future of Electric Power in America: Economic Supply for Economic Growth*, Report of the Electricity Policy Project, DOE/PE-0045, June. Washington, D.C.

125. John R. Siegel. 1983. "Changes in the Real Price of Electricity: Implications for Higher Load Growth," *Public Utilities Fortnightly*, Sept. 15, 1983, pp. 32-42.

126. Gas-Cooled Reactor Associates. 1982. *HTGR Steam Cycle/Cogeneration Lead Plant Design and Cost Report*, GCRA 82-010, Vol. 1-3, July. San Diego, California.

127. M.L. Myers, Private Communications October 11 and 17, 1983.

128. Gas-Cooled Reactor Associates, pp. 3-11.

129. Westinghouse Electric Corporation. 1982. *Westinghouse's New 2-Loop Nuclear Power Plant*, Draft Report, Water Reactor Division. Pittsburgh, Pennsylvania.

130. G.R. Smallen and J.G. Delene. September 1980. *Power Generation Costs for Alternate Reactor Fuel Cycles*, ORNL/TM-7376. Oak Ridge, Tennessee: Oak Ridge National Laboratory.

131. OECD Nuclear Energy Agency and International Atomic Energy Agency. 1982. *Uranium*, a joint report. Vienna, Austria.

132. Karl Cohen. 1983. "Global 2000 Revised Nuclear Power."

133. OECD Nuclear Energy Agency.

134. International Atomic Energy Agency. 1980. *International Nuclear Fuel Cycle Evaluation*, Summary Volume, INFCE/PC/2/9, January. Vienna, Austria.

135. Rockwell International.

136. H.A. Bethe. 1979. "Fusion Hybrid," *Physics Today* *32*: 44-51. (May)

137. Energy Research and Development Administration. 1977. *Proceedings of an Information Meeting on Accelerator-Breeding*, CONF-770107, held at Brookhaven National Laboratory, January 18-19. Upton, New York.

138. U.S. Department of Energy. 1980. *Nuclear Proliferation and Civilian Nuclear Power*, Vol. 1, Program Summary, Report of the Nonproliferation Alternative Systems Assessment Program. Washington, D.C.

139. International Atomic Energy Agency.

140. U.S. Congress.

141. Swedish Atomic Forum. 1983. *Swedish Nuclear News*, October No. 2, p. 5.

142. C.C. Burwell and J.A. Lane. 1980. *Nuclear Site Planning to 2025*, ORAU/IEA-80-5(M). Oak Ridge, Tennessee: Institute for Energy Analysis, Oak Ridge Associated Universities.

143. Barkenbus, "Prospects and Opportunities."

144. Barkenbus, "An Assessment of Institutional Alternatives."

145. Barkenbus, "Prospects and Opportunities."

146. Atomic Energy Society of Japan/International Atomic Energy Agency. 1983. International Meeting on Recovery of Uranium from Seawater, October 17-19. Tokyo, Japan. (Proceedings to be published.)

COMMENTS BY MEMBERS OF THE SECOND NUCLEAR ERA ADVISORY COMMITTEE

At the final meeting of the Advisory Committee of the Second Nuclear Era Project (in the summer of 1983) members of the committee were invited to submit their own personal comments on the study. Three members of the committee did prepare such personal comments and these are included in the following section.

Comments by Hans A. Bethe, Professor of Physics, Cornell University

Like the authors of this report, I believe that nuclear power will be increasingly important in the future, but that for the next 5 or 10 years there will be a hiatus in orders for nuclear plants in the United States. This is a very good opportunity to assess the present status of nuclear power, and possible changes to prepare for the resumption of nuclear power construction in the future.

This is an excellent report, based on very thorough research. It should be made widely available, both to the public and to the nuclear industry as well as the government.

I was very much impressed by the thorough discussion of nuclear safety. The method of Probability Risk Assessment (PRA) is used. It is found that before the TMI accident the accident probability was higher than had been estimated in WASH-1400. But since TMI, partly on orders by the Nuclear Regulatory Commission, but partly by voluntary action of the utilities, the risk has been greatly diminished so that it is now rather lower than WASH-1400 indicated. Further, additional safety measures for future light water reactors have been conceived. Therefore the report concludes that the present reactors are certainly safe enough for a world with 500 reactors, i.e., in the next 20 years. I concur in this conclusion, and it is my impression that they may still be safe for a world with many more reactors in the future.

Especially important is the great reduction of the Source Term in view of the TMI experience. It seems that the release of radioactivity in a reactor accident is likely to be much less than was expected in WASH-1400, and that accidents with very large releases and high hazards to the public are by now exceedingly improbable. This should be well publicized, and might contribute to alleviation of public anxiety.

In spite of my assessment of nuclear safety which is more optimistic than that of the report, I concur that it would be highly desirable to design and build a supersafe reactor of the PIUS type. The money which the government has saved by the cancellation of the Clinch River Breeder could very profitably be spent on the PIUS Project.

The report rightly emphasizes that perhaps the most important reason for the lack of orders for reactors in the United States is economics. The median cost of new reactors is too high, and especially it varies too much from case to case, and is too unpredictable. Standardization of the design would help greatly, as it has helped in countries like France where nuclear power is proceeding at a rapid rate.

In conclusion, I hope this report will be widely read by all groups concerned. It is an invaluable source of information.

Comments by S. David Freeman, Director, Tennessee Valley Authority

The heart of this study directed by Alvin Weinberg is its recommendation that the PIUS reactor--or an equivalent inherently safe reactor--should be built at once. It is a bold recommendation from a leading member of the "nuclear family" who is still open to new ideas.

The Weinberg study makes a solid case for its recommendation. Indeed it significantly understates the need for the development of an inherently safe reactor concept.

The prevailing opinion in the nuclear industry is that marginal improvements on existing reactor designs will be good enough. This opinion is at odds with prevailing public opinion. The large numbers of people concerned about nuclear power and their representatives in Congress have little or no faith in "event tree" analyses that failed to predict TMI. In my view the public will be unmoved by being told that there will be reactor failure every 10^5 years rather than every 10^4 years.

People think that anything that can go wrong will go wrong. That common sense judgment of public opinion may well be better than the "event tree" analysis that does not fully reflect the extent to which some operators will make mistakes, to which some plants will be poorly built and to which management attention to safety may be lax at some of 60 utilities that will soon be operating nuclear units.

The industry criticizes NRC licensing but the regulatory process simply mirrors the lack of public confidence in the existing reactor designs and reflects the real need for expensive safeguards to try to reduce the risks to levels the public may accept. That same regulatory process would also be responsive to the far less stringent safeguards needed for a reactor that does not pose the awesome risk of a meltdown and cannot be the victim of operator error.

In my view developing an inherently melt-down proof nuclear reactor is a useful option for the nation to help reduce oil imports that add to the risk of war in the Middle East and to reduce our consumption of air polluting fossil fuels that pose dangers from acid rain and CO_2 buildup that may well be greater than the danger from a melt-down proof reactor. This need for a safer nuclear option will exist for decades even if we launch an all-out conservation program and accelerate the R&D to harness the sun and develop a sustainable source of energy.

The future for the nuclear option in the United States is in great jeopardy today because the existing designs require so many protective add-ons to be made safe enough that they have become uneconomical for new plants. The value of this report is it suggests that there are technical options that can be safe enough as well as economical.

The future of nuclear power may very well rest on the manner in which this excellent report is received, especially by the proponents of nuclear power. The R&D necessary to perfect these options is a Federal responsibility but the Federal government cannot be expected to fund it if the nuclear industry does not realize that the development of these concepts is a life and death matter for them as well as useful for the nation.

Comments by H. G. MacPherson
Consultant to the Institute for Energy Analysis

In my opinion this is an excellent summary of the various factors involved in our current nuclear moratorium and of the prospects for emerging from it. I agree in general with most of what is said, including the two main conclusions, although I differ in emphasis and in some details, as indicated below.

1. The impressive efforts by INPO to improve nuclear utility management, combined with some of the changes in reactor hardware and control room equipment now being made, have decreased the likelihood of a core damaging accident by at least the factor of 3 to 6 cited in the report, in my opinion. With the probability of such an accident solidly below 10^{-4} per reactor year, there is no objective reason why a utility executive should fear losing his investment in a nuclear reactor from an accident. Furthermore, with the new, more realistic estimates of the amount of radioactivity that might escape in case of such an accident, the risk to the public is much lower than any limit that might be logically set. If the numbers given on pages 58-59 are multiplied out, it becomes clear that, among the many possible dangers faced by mankind, concern with harm from a reactor accident deserves no more than a few minutes attention.

However, I differ rather strongly with the statement on page 88 that, as more reactors appear on the world scene, additional safety is required. I see no rational basis for such a statement.

2. In coming to the conclusion above, I take advantage of a background that differs considerably from that of the average citizen, politician, newspaper reporter or TV anchor man. With an engineering background I can make use of my limited knowledge of probability and statistics, I can develop an understanding of how the various safety systems work and read reports of their tests, and I even have a long familiarity

with radiation and some of its effects. Therefore I can feel quite confident in my perception of reactor safety.

In contrast, most average citizens, politicians and news reporters have neither the background nor the time to make individual judgments of their own about the safety of reactors, and so must depend on the advice of others. In so doing they listen to people holding views similar to mine, but they must also listen to others of opposite view. Some of these nuclear critics appear to have formal qualifications equal or superior to my own, and thus their opinions cannot be dismissed readily. In giving voice to their opposition to nuclear power they appear to be bucking the establishment. Since anti-establishment views are considered newsworthy, a number of them have gained national reputations and appear repeatedly in supposedly impartial debates. The net effect of this dichotomy of opinion is that the public is sharply divided and it may not be possible to gain a rational consensus. Thus, present day reactors may not be acceptable, no matter how safe I say they are, and it may be that a new reactor that is transparently much, much safer is needed.

At the start of the Second Nuclear Era study I had little confidence that it would be possible to find any reactor that was demonstrably enough safer than LWRs to make any real difference in its acceptability. I was at least moderately familiar with essentially all reactor types that have been constructed or seriously proposed, and although some of them have what are called "inherently safe" features, they all are subject to some conceptually possible accident that would release at least moderate amounts of radioactivity. It was therefore exciting to hear from Mr. Hannerz about the PIUS reactor, which I consider to be qualitatively different from any other proposal in the field of reactor safety. The essential feature is the open coupling of the reactor to an alternate cooling system that takes hold automatically should any disturbance of normal heat transfer occur. The alternate cooling water contains boron to provide automatic reactor shutdown. By placing the system in a large concrete bottle, cooling for a number of days is provided and the system is made relatively resistant to terrorist attack. Saboteurs could shut down the power production but they could not readily cause radioactivity to escape.

I do not agree with the implication of the statement on page 45 that "there may be a number of avenues to a supersafe reactor." In my opinion the PIUS concept is unique in this respect. The other reactor concepts discussed on pages 40-45 are all vulnerable to readily imagined core damaging accidents for which prevention of public exposure would depend on engineered safeguards of some kind. I am especially puzzled by the discussion of an "inherently safe" LMFBR. Fast reactors are "inherently" plagued with the specter of a reactivity excursion, about which there is a large volume of technical literature. Although a fast reactor can probably be made as safe as an LWR, I don't see how public fears can be completely eliminated.

I strongly support the proposal for the development of the PIUS reactor. It may be needed for the revival of our nuclear power industry, and it would certainly be useful in places where political stability cannot be guaranteed.

3. I believe we are in agreement that eventually the world will need to use the energy contained in ^{238}U and thorium. At the start of this study I wondered whether it was worthwhile to develop any new reactor that was not capable of breeding. Would there be a useful period between completion of its development and the appearance of a scarcity of uranium? In the section on "Fuel Assurance" it is shown that, with present trends for the rate of increase in usage of electricity, the date at which uranium becomes very expensive is "sometime after 2025." Even then the very high capital cost of the LMFBR, the only breeder being actively developed, would probably prolong the economic preference for converter reactors for decades beyond that. Thus there would appear to be a substantial time window during which the PIUS reactor would be viable.

I do not have a better analysis to present, but I do call attention to the fact that the extrapolation of present trends can be treacherous.

In fact, it was in large part the extrapolation of the 7 percent per year increase in electricity use beyond 1973 that brought on the present moratorium on power plant orders. Despite this reservation about predicting the future, I agree that it may very well be the middle of the next century before breeders are needed badly. But eventually, breeding will be needed and I strongly support the recommendations on page 93, although I would be more specific in suggesting that the next years be devoted to exploring alternates to the LMFBR. All of the evidence to date indicates that the LMFBR will continue to cost about twice as much as an LWR, and it will be nearly impossible for uranium to cost enough to make the overall economic comparison favorable to the LMFBR. For years, optimists have been predicting that the cost will come down, but such a trend would be counter to that experienced with LWRs. Among the alternate potential breeders I personally favor the Molten Salt Reactor which could reasonably be expected to cost less than the LMFBR. The Gas Cooled Fast Reactor should also be a candidate to see if its distinguishing features can lead to lower costs.

Mrs. LLOYD. Thank you very much, Dr. Weinberg.

Dr. Lester, we look forward to your testimony. Please proceed. And for all of our panelists here, your complete statement will be made part of the record, and you may proceed as you wish to summarize in whatever manner that you see fit.

STATEMENT OF DR. RICHARD K. LESTER, ASSOCIATE PROFESSOR OF NUCLEAR ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dr. LESTER. Thank you.

I'm not sure whether—is this microphone working?

Mrs. LLOYD. Maybe Dr. Weinberg will share his microphone with you, since we found out it was successful.

Dr. LESTER. Madam Chairman, I very much appreciate the opportunity to appear before you to discuss the future direction of Federal nuclear research and development programs.

To state that the American nuclear power industry is today at a crossroads is surely no exaggeration. The choice facing its leaders, to put it bluntly, is whether nuclear energy will again become a viable option for the Nation's electric utilities, or whether, instead, it will remain, as it has been for some time, an unacceptable one.

The issue is of considerable importance to the utilities and to the Nation as a whole. Though many are ready to write off the nuclear option entirely, there is nothing inherently impractical about the use of nuclear fission as a way to generate electricity. And there is a broad range of plausible circumstances under which the unavailability of the nuclear option would impose substantial economic and environmental penalties on this Nation by the turn of the century.

Therefore, the electric power industry, the nuclear supply industry, and the Government should carefully and without prejudice explore the conditions that would foster a revitalization of the nuclear option.

There may still be those who believe that developments outside the industry—for example, a sustained upturn in electricity demand or another oil shock—will be sufficient in themselves to overcome its present problems. But the recognition is growing that some fundamental changes will be required within the industry if nuclear power is again to become an economic option.

The nature of those changes is the question before us today. More particularly, the question is whether innovations in nuclear powerplant technology have a significant role in this regard and what part the Federal Government could play in bringing them about.

I believe that technological changes are in prospect which could substantially improve the outlook for a resumption of nuclear ordering in the 1990's, which are within reach in the time available, and which would not be achievable without Federal participation.

But I shall also argue that too much should not be expected of technological advances alone; that a focus on technological innovation, to the neglect of parallel organizational reforms, will in all likelihood lead to failure; and that while the Federal role in both of these areas will be crucial, the nature of that participation may need to be different from the historical role played by the Federal Government in support of a nuclear option.

An effective prescription first requires an accurate diagnosis. Utilities find the nuclear option unattractive today because they do not believe that they can build and operate nuclear powerplants without incurring unacceptable financial risks. To ascribe this to overzealous regulators and a poorly informed public is to oversimplify matters to a misleading degree. Equally inadequate is the suggestion that there is something intrinsically noncompetitive about the light water reactor. Rather, the present situation is the result of a complex, unhappy synergy between certain characteristics of light water reactor technology, the highly fragmented structure of the U.S. electric utility industry, and the sociopolitical environment in which the industry must function.

There is no simple fix for these problems, technical or otherwise. Corrective actions of several kinds will be needed.

Organizationally, the most important need is for reform which would reduce the uncertainties now perceived by utilities to be associated with nuclear investments. This may entail shifting some of the financial risks of construction to the nuclear plant suppliers. It may also require that construction is limited to standardized, prelicensed designs. It will certainly require strengthening the technological and management capabilities of utilities engaged in nuclear projects. Unless the wide variation in nuclear utility performance is sharply narrowed, public confidence in the industry as a whole will remain low, and the NRC will be unwilling and unable to move away from the prescriptive mode of regulation that the industry has found so burdensome.

Technologically, the primary need is for simpler, less costly nuclear powerplants which impose fewer financial and managerial burdens on their builders and which can be operated more reliably and maintained more easily than the current generation of light water reactors.

These goals seem self-evident in the light of recent utility experience. They are, however, quite different from the traditional view of the role of reactor innovation; that is, to design and build reactors that consume a minimum of uranium.

Eventually, there may be a time when high uranium costs will induce a shift to the LMFBR or to alternative breeder concepts, but those circumstances now seem very unlikely to arise for several more decades, and certainly will not arise at all if the other problems which are currently inhibiting nuclear power growth are not resolved first.

The changed outlook for nuclear power demands a fundamental reordering of priorities for the Nation's nuclear innovation efforts. A continuation of breeder reactor development is justified as long as there is a reasonable possibility that nuclear power will be called on to make a long-term contribution to the Nation's energy needs. In my view, there is at present no sound basis on which to rule out that possibility.

On the other hand, a continuation of breeder development is logical only if there is reasonable confidence that the more immediate obstacles facing nuclear power will be overcome. I do not believe that a liquid metal cooled fast reactor program, however reconstituted, can offer any significant contribution to the resolution of those problems in the marketplace before the turn of the century. Consequently, it is important to guard against the risk of a continuing breeder program diverting attention and resources from efforts which are more likely to be effective in the shorter term.

Of the technological approaches that might contribute to those nearer- term goals, I'd like to mention three in particular:

First, a reduction in reactor size.

Second, an increased emphasis on plant fabrication in a controlled environment, with a consequent reduction in the amount of onsite construction.

And, third, a shift in the direction of greater inherent safety in nuclear powerplant designs.

The most important question concerning reactors which offer a higher degree of inherent safety than conventional light water reactors is whether they also offer the prospect of lower and more predictable electricity costs. The ultimate test of such reactors will not be whether or by how much they reduce the risk to public health and safety compared to conventional light water reactors, but whether, as a result of hardware simplifications, changes in construction techniques, and changes in investor and public risk perceptions, they can compete economically.

It is also important to remember that no matter how innovative the approach to design and construction, the viability of the product in the marketplace will also depend on how reliable it is and on how easily it can be maintained.

The major U.S. light water reactor vendors are currently developing the next generation of light water reactor designs. These new designs incorporate a substantial number of incremental improvements, but they do not go very far in the direction of addressing the basic disincentives to nuclear ordering that I have mentioned.

Given the current outlook for the nuclear option and the magnitude of the investments required, none of the more radical technical approaches to these problems could be developed without Federal support.

I believe that the Government should make a commitment in this area as part of a larger national effort to find ways to make nuclear power a viable option for the Nation's utilities in the 1990's. However, I believe that Federal participation should be contingent on an unambiguous indication of interest and commitment on the part of the utility industry itself.

Finally, and perhaps most important, I do not believe that a national effort to develop improved nuclear reactor technologies should deflect attention from the crucial task of finding ways for the electric utility industry to overcome its structural weaknesses, to think more coherently and strategically about its technological needs in the nuclear field, and collectively to play a more active role in ensuring that those needs are satisfied.

That concludes my prepared remarks.

[The prepared statement of Dr. Lester follows:]

PREPARED STATEMENT OF RICHARD K. LESTER, ASSOCIATE PROFESSOR OF NUCLEAR ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Madam Chairman and members of the Committee, I appreciate the opportunity to appear before you to discuss the future direction of Federal nuclear research and development programs. It is my understanding that this subject will be developed largely through questioning of the panel in a number of specific areas, but prior to this I would like to offer some general comments which may help to place these issues within their larger context.

To state that the American nuclear power industry is today at a crucial crossroads is surely no exaggeration. The choice facing its leaders, to put it bluntly, is whether nuclear power will again become a viable option for the nation's electric utilities, or whether instead it will remain, as it has been for some time, an unacceptable one.

The issue is of considerable importance to the utilities, and to the nation as a whole. Though many are ready to write off the nuclear option entirely, there is nothing inherently impractical about the use of nuclear fission as a way to generate electricity. And there is a broad range of plausible circumstances -- even including those in which electricity demand grows a good deal more slowly than the most recent mid-range forecasts of the government and the electric power industry -- under which the unavailability of the nuclear option would impose substantial economic and environmental penalties on the nation by the turn of the century. Therefore, the electric power industry, the nuclear supply industry, and the government should carefully and without prejudice explore the conditions that would foster a revitalization of the nuclear option.

There may still be those who believe that developments outside the industry -- for example, a sustained upturn in electricity demand, or another oil shock -- will be sufficient to overcome its present problems. But, if so, their ranks are rapidly thinning, and the recognition is growing that some fundamental changes will be required within the industry if nuclear power is again to become an economic option.

The nature of those changes is the question before us today. More particularly, the question is whether innovations in nuclear power plant technology have a significant role in this regard, and what part the Federal government could play in bringing them about. Without speculating on whether such innovations would actually be necessary for the revitalization of the nuclear option, I believe that technological changes are in prospect which could substantially improve the outlook for a resumption of nuclear ordering in the 1990s, which are within reach in the time available, and which would not be achievable without Federal participation. But I shall also argue that too much should not be expected of technological advances alone; that a focus on technological innovation to the neglect of parallel organizational reforms will in all likelihood lead to failure: and that while the Federal role in both of these areas will be crucial, the nature of that participation may need to be quite different from the historical role played by the Federal government in support of the nuclear option.

An effective prescription first requires an accurate diagnosis. Utilities find the nuclear option unattractive today because they do not believe that they can build and operate nuclear power plants without incurring unacceptable financial risks. To ascribe this -- as the nuclear power industry has long done -- to overzealous regulators and a poorly informed public is to oversimplify matters to the point of misrepresentation. Both factors are real enough, but in large measure contingent on more fundamental problems. Equally inadequate is the suggestion that there is something instrinsically noncompetitive about the light water reactor -- witness the more successful efforts of several other countries with very similar technology. Rather, the present situation is the result of a complex, unhappy synergy between certain characteristics of LWR technology, the highly fragmented structure of the U.S. electric utility industry, and the sociopolitical environment in which the industry must function.

There is no simple 'fix' for these problems. Corrective actions of several kinds are needed. The general directions are clear, even though the detailed specifications are still to be determined. Organizationally, the most important need is for reforms which would reduce the uncertainties now perceived by utilities to be associated with nuclear investments. This may entail shifting some of the financial risks of construction to the nuclear plant suppliers. It may also require that construction is limited to standardized, prelicensed designs. It will certainly require strengthening the technological and management capabilities of utilities engaged in nuclear projects. Unless the wide variation in nuclear utility performance in construction and operation is sharply narrowed, public confidence in the industry as a whole will remain low, and the Nuclear Regulatory Commission will be unwilling and unable to move away for the prescriptive mode of regulation that the industry has found so burdensome.

Technologically, the primary need is for simpler, less costly nuclear power plants, which impose fewer financial and managerial burdens on their builders and which can be operated more reliably and maintained more easily than the current generation of light water reactors.

These goals seem self-evident in the light of recent utility experience. They are, however, quite different from the traditional view of the role of reactor innovation. This has held that depletion-driven increases in the price of uranium would pose the primary threat to the competitiveness of the nuclear option. In this view, the chief goal was to design and build reactors that consumed a minimum of uranium.

Eventually, there may be a time when high uranium costs will induce a shift to the liquid metal cooled fast breeder reactor, or to an alternative breeder concept. But those circumstances now seem very unlikely to arise for several more decades, and certainly will not arise at all if the other problems which are currently inhibiting nuclear power growth are not resolved first.

The present portfolio of nuclear research and development by and large reflects the traditional view of reactor innovation. The changed outlook for nuclear power demands a fundamental reordering of priorities for the nation's nuclear innovation efforts. A continuation of breeder reactor research and development is justified as long as there is a reasonable possibility that nuclear power will be called on to make a long term contribution to the nation's energy needs. In my view, there is at present no sound basis on which to rule out that possibility. On the other hand, a continuation of breeder research and development is logical only if there is reasonable confidence that the more immediate obstacles facing nuclear power will be overcome. I do not believe that a liquid metal cooled fast reactor program, however reconstituted, can offer any significant contribution to the resolution of those problems in the marketplace before the turn of the century. Consequently, it is important to guard against the risk of a continuing breeder program diverting attention and resources from efforts which are more likely to be effective in addressing those problems in the shorter term.

Of the technological approaches that might plausibly contribute to the nearer-term goals, three seem particularly germane:

First, there is reason to believe that a reduction in reactor size would help to improve the competitive position of nuclear power in the U.S. utility sector. The presumed benefits include simpler designs, shorter construction lead-times, reduced utility financial exposure, and better matching of capacity additions with utility load growth. There are still outstanding technical issues regarding the opportunities for design simplification that would accompany different reductions in LWR unit size.

Second, an increased emphasis on plant fabrication in a controlled environment, with a consequent reduction in the amount of onsite construction, seems likely to lead to lower and more predictable construction costs and enhanced quality control.

Third, a shift in the direction of greater 'inherent' safety in nuclear power plant designs could also enhance the competitive position of the nuclear option. In essence, the idea of inherent safety is to lessen dependence on automated engineered safety systems and rapid operator actions for removal of the radioactive decay afterheat in the core after fissioning ceases, and to rely more heavily on passive cooling processes. The full potential of the concept is captured in the PIUS reactor design developed by ASEA-ATOM in Sweden and in the small, modular high temperature gas reactor systems under development in the Federal Republic of Germany and this country. Both reactor systems lay claim to 'walk-away' safety, meaning that significant overheating of the core can be avoided in the absence of any active cooling systems. The property of inherent safety is one of degree, however, and, though less dramatic, evolutionary improvements in conventional light water reactor systems can also be envisaged which would place more reliance on passive cooling and allow operators more time to take effective countermeasures.

The term 'inherent safety' is potentially misleading in two respects. First, there is a danger that it may be confused in the public mind with 'absolute safety,' something which no nuclear reactor can ever offer, whatever its design. Second, it tends to conceal the fact that such designs are also intended to reduce the likelihood of events that would cause major damage to the core without ever threatening the safety of the general public.

Whatever the appellation, the most important question concerning reactors which offer a higher degree of inherent safety than conventional light water reactors is whether they also offer the prospect of lower and more predictable electricity costs. The ultimate test of such reactors will not be whether or by how much they reduce the risk to public health and safety compared to conventional LWRs, but whether they can compete economically. In this regard, greater dependence on passive safety features may bring with it several potentially important economic benefits, for example:

- the elimination of complex, costly engineered safety systems;

- by making the safety-related performance of the nuclear core independent of events elsewhere in the plant, there will be correspondingly less need for specialized nuclear construction techniques and stringent quality assurance programs in the balance of plant; today these requirements account for a substantial fraction of the cost of conventional light water reactors;

- reducing or even eliminating the dependence on engineered safety systems will tend to ease the pressure on the regulators to 'ratchet up' the design by adding another layer of safety requirements; for conventional LWRs, that pressure has been difficult to resist in the absence of a clear answer to the politically difficult question of 'how safe is safe enough?'; thus, inherently safe designs can contribute to the achievement of greater regulatory stability.

Not enough is known yet about the specific design approaches to increased inherent safety to permit accurate quantification of these possible benefits. What is certain, however, is that no matter how innovative the approach to design and construction, the viability of the product in the marketplace will also depend on how reliable it is and on how easily it can be maintained. Utilities have encountered an unexpectedly large number of difficulties in operating and maintaining the present generation of light water reactors, and seem likely to be more discerning and demanding with regard to these questions than they have been in the past. Reliability and maintainability objectives must form an integral part of any serious effort to develop novel nuclear power plant designs promising greater inherent safety.

The role of the Federal government

The major U.S. light water reactor vendors are currently developing the next generation of LWR designs, without U.S. government support but in two cases in collaboration with foreign partners. These new designs incorporate a substantial number of incremental improvements, but they do not go very far in the direction of addressing the basic disincentives to nuclear ordering in the U.S. that I have mentioned previously. Presumably their developers believe that these problems will be addressed by other means, or not at all.

Given the current outlook for the nuclear option, and the magnitude of the investments required, none of the more radical technical approaches to these problems -- whether involving more far-reaching modifications to LWR technology or different reactor systems -- could be developed without Federal support, though some would require less than others.

The electric utility industry -- fragmented, locally regulated, and poorly coordinated -- has demonstrated a chronic inability to prepare itself adequately for its commitment to nuclear technology. The combined actions of each utility responding to its perceived needs have fallen well short of the needs of the industry as a whole. In the nuclear field, the utilities have been largely passive consumers of technology that others have developed. This is consistent with the traditional behaviour of the utilities in other areas of electric pwoer technology. But while this approach has generally been adequate in those cases, in the case of nuclear power technology, which has turned out to demand so much of its users as well as of its developers, a passive approach has often been very costly.

Whether the industry addresses this deficiency or not is, I believe, the key to the future of the nuclear option in the United States. On present evidence, the industry is not about to solve the problem alone, and indeed still may not have even fully recognized it. Consequently, I believe that the most important general task facing the Federal government in the civilian nuclear field is to help the electric utility industry to overcome its structural weaknesses and to think more coherently and strategically about its technological needs, and to play a more active role in ensuring that they are satisfied.

This is a somewhat unaccustomed role for the Federal government. Non-monetary participation may be just as important here as actions demanding budgetary consideration. And clearly, a major government financed and led advanced reactor development program taken on its own would not be an effective response, even if it were politically feasible. Not only is the Federal government and its national laboratories not particularly adept at picking technological winners for commercial application, but an attempt to do so would tend only to perpetuate the passive status of the utilities. Rather, the government should seek to use its nuclear research and development budget as a vehicle to engage the electric utilities in preparing more actively for their own technological future.

This concludes my prepared remarks. I will now try to respond to specific questions on these and related subjects.

Mrs. LLOYD. Thank you very much, Dr. Lester, for your testimony. Dr. Lester is an associate professor in the Department of Nuclear Engineering at the Massachusetts Institute of Technology.

Our next witness is Mr. Charles Jones, president of NUS Corp. and, of course, Mr. Fred Webber, Edison Electric Institute.

I would like to call the attention of those in the audience that Dr. Shelby Brewer will not be with us this afternoon, but he will be providing testimony for us tomorrow.

Please proceed, Mr. Jones.

STATEMENT OF CHARLES F. JONES, PRESIDENT, NUS CORP., GAITHERSBURG, MD.

Mr. JONES. Thank you, Madam Chairman.

I am pleased and grateful for this opportunity to present you with some of my thoughts on what it will take to strengthen the nuclear option for the generation of electricity in the United States.

I have provided the committee with copies of my full testimony, but it is rather lengthy and, therefore, I will try to summarize the major points that I have made within the 5 minutes that the guidelines allow me.

Today in this country the nuclear option——

Mrs. LLOYD. Mr. Jones, I think we're going a little bit over 5 minutes today, so you can relax just a little bit more.

Mr. JONES. OK.

Mrs. LLOYD. But your complete testimony will be made a part of the record.

Mr. JONES. Thank you.

Today in this country the nuclear option is in trouble. It is not the basic technology that is at fault. Nuclear powerplants have been operating successfully since 1957. The major problem seems to be that the product and the system that we have for delivering that product are not now compatible with the regulatory environment.

The traditional method for building powerplants in this country is to design and construct a one-of-a-kind, customized facility using an ad hoc crew of professional engineers, managers, and craftsmen. It is a method that has worked well since the beginning of electricity.

The nuclear plants of the late 1950's, the 1960's, and the early 1970's were built using this philosophy. The problem today is that the regulatory environment of the 1980's is not the regulatory environment that existed in the late fifties, the sixties, and the seventies.

The regulatory system has become so conservative, so bureaucratic, and so demanding in the sheer weight and detail of its supervision, procedures, and requirements that it is totally impractical for a utility to attempt to design and built a nuclear powerplant today using past methods.

If we are going to have a second generation of nuclear powerplants, we're going to have to develop new systems of doing business that are technically and economically compatible with the regulatory system. We are going to have to go to completely standardized designs and build these plants with permanent trained and certified work forces.

A practical means of making these two changes is to go to smaller, factory-fabricated, standardized generating units, plants in the range of 200 to 400 megawatts electric.

If the industry could limit itself to three or possibly four standard designs at any one time, then we could cut the incremental cost and time for engineering, design, and specifications to something close to zero. We could reduce the time needed to license each new unit to a few months or less.

Plants would be built in a factory environment where both productivity and quality could be significantly improved. Factory-fabricated, standardized generating units could cut the average time for a new plant from order to operation to something under 4 years. The savings on interest alone could reduce the cost of a new plant by as much as 30 percent.

Factory-assembled modules could be moved to sites over land or by a combination of water and overland routes. Complete plants could be moved to sites by one or more barges which were designed and built to be an integral part of the plant.

A very large part of this country can be served by sites which are accessible by water.

A small nuclear plant in the range of 200 to 400 megawatts would have many advantages, especially in a period of low load growth and a time of high rates of interest and inflation. The smaller size is also much more suitable for a standard design to be built using factory-assembled modules. These advantages could more than make up for the economies of scale that we believed, or were believed to be the argument for going to the larger, 1,000- and 1,200-megawatt units.

If this concept is to be thoroughly tested, the market and feasibility studies, the proprietary designs, and the many institutional questions have to be the ultimate responsibility of the private sector. However, in the near term there are some things that this committee could do to move the concept forward.

The nuclear industry in this country is well established. It is large enough and old enough so that any significant change in direction will have to overcome a great deal of inertia that is sheltered by, to some degree at least, by vested interest in both the private sector and Government.

Given this kind of an environment, this committee could be helpful by initiating preliminary studies and research to stimulate and give momentum to the concept of one design, factory-built nuclear powerplant modules.

Thank you.

[The prepared statement of Mr. Jones follows:]

TESTIMONY OF CHARLES F. JONES

Before the
Subcommittee on Energy Research and Production
Committee on Science and Technology
United States House of Representatives

Washington, D.C. February 7, 1984

Madam Chairman:

My name is Charles F. Jones. I am the President and Chief Executive Officer of NUS Corporation of Gaithersburg, Maryland. NUS Corporation is an engineering and consulting firm of approximately 1500 employees. The company specializes in the planning, design, and operational support of nuclear and fossil-fueled energy systems and nuclear and hazardous-waste management programs. I have been involved with nuclear power since 1954, and NUS has been very active in this technology since its founding in 1960. I am pleased and grateful for the opportunity to present you with some of my thoughts on what it will take to strengthen the nuclear option for the generation of electricity.

Nuclear power has come a long way since the first commercial unit went on line at Shippingport, Pennsylvania, on December 18, 1957 (just three years and four months after the project was initiated). Today, in this country, we have 83 nuclear plants with operating licenses and 60 more units under construction. Nuclear power is currently generating 13 percent of this country's electrical energy, and it will be up to 20 percent by 1990. Light-water-reactor technology, born here in the United States, is going strong in Japan, Korea, Taiwan, the Philippines, Mexico, Brazil, Spain, Italy, France, Germany, Belgium, Switzerland, the Netherlands, Sweden, Finland, Yugoslavia, all of eastern Europe, and now England. Before this year is over, there may even be a project in mainland China. By almost any standard that you could use, commercial nuclear power has been, is now, and should continue to be a viable option for the generation of electric power. It has a perfect safety record. It is the low-cost fuel. It has the least impact on the environment of any method of generating electricity. It is the most economically and politically stable fuel supply that we or any other nation has to work with. It is a reality. But here in the United States it currently has some very difficult problems.

Nuclear power is taking a lot of heat these days. It doesn't make much difference what our choice of reading material is, almost all of the news is bad. The New York Times, The Washington Post, The Wall Street Journal, Business Week, Time Magazine, Newsweek, and any one of the local papers all throw it right up to us in headlines: nuclear power looks like a loser.

The media keep hammering away at the financial embarrassments that have occurred; the emphasis of late is on the Washington Public Power Supply System's nuclear problems and on cancellation of the Zimmer and Marble Hill plants after billions of dollars had been poured, welded, and bolted into the ground. We keep hearing about there being no new orders since the mid-1970s, the two or three dozen cancellations in the last five years, and the endless delays at Shoreham, Diablo Canyon, and many other sites. Every announcement of an NRC fine seems to carry with it the stigma of criminal negligence. The TMI story gets dragged out over and over again, every time someone needs a horror story to get readers' attention. Steam-generator problems and pipe cracking are presented as proof that engineers don't know what they are doing. QA documentation problems are presented as being synonymous with poor-quality work. Every disgruntled employee turned whistle-blower is presented as a hero, and every industry executive is cast in the role of someone who will put the profit motive ahead of public safety. We are confronted with story after story of gigantic cost overruns, lawsuits by stockholders, local governments refusing to participate in emergency planning, executives being fired, rate requests being turned down because of nuclear plant problems, bond ratings being lowered because of nuclear plant delays, and, of course, scare stories about radiation. The Clinch River Breeder Reactor finally gets dropped, and the USA goes from leader in technology to follower. This country will spend more money on moon shots, space shuttles, and now space stations, without any questions, but the breeder program is too expensive. The people do not want nuclear waste in their back yards or on their highways, but they accept the more volatile, corrosive, toxic, and explosive chemical wastes in much greater volumes without complaint. The ANS, the AIF, and the U.S. Committee for Energy Awareness spend millions of dollars trying to get the real facts before the public, but the fiction of Jane Fonda's "China Syndrome" and the Silkwood story are what people want to believe.

What has happened to the success story that is nuclear power? Something has obviously gone wrong. The people who make the decisions on power plants, utility managements, are not now inclined to order any new nuclear plants, not in this country, not in this political environment. In France, yes; in Germany, yes; in Japan, Korea, Taiwan, and mainland China, yes--but not at home. Why? Because it is just too risky, financially risky. How many of you have heard a utility executive say, "I am going to build coal. It is the wrong decision for my customers, but I can't take the risks that go with trying to build nuclear." This executive cannot see ahead 12 years, the time it takes to build the first-of-a-kind unit. He doesn't know what it will cost when he gets there. He can't afford the cost of money over that length of time. He can't predict the regulatory environment, he can't predict White House policy, and he can't predict local political actions. There are just too many uncertainties that are far beyond his control. Even if an executive were willing to take another chance on nuclear power, his board of directors wouldn't buy it, the banks wouldn't fund it, and the stockholders would sue.

It is not the basic technology that is at fault. We have proven that, here at home and overseas. The problem is that the product and the system we have for delivering the product is not now compatible with the regulatory, financial, and political environment that we must operate in or that we are likely to operate in in the future. The traditional method for building power plants (one that has lasted since the beginning of electricity and that covers nuclear, hydroelectric, and fossil-fueled plants), is to have the plant operator (the utility) hire an engineering firm to design a one-of-a-kind facility, using engineered equipment supplied by hundreds and perhaps thousands of different manufacturing firms. The operator usually has a role in the design and decisionmaking process. Construction management is assigned to the engineer, to the operating company, or sometimes to a third party. Actual construction is contracted out to any number of firms specializing in the major construction disciplines. Labor is organized into as many as a dozen different unions. Construction usually gets under way long before all of the design and engineering are completed. Some of the engineering and design is actually done in the field. The facility is a one-of-a-kind, customized facility, designed and constructed by an ad hoc crew of professional engineers and craftsmen.

The project is paid for by the operating company as the work is done. The risk is almost solely that of the operating company. For nuclear power plants, this process is further complicated by the fact that the Nuclear Regulatory Commission is empowered to unilaterally require design changes at any time during the process, even after the plant has been completed and is in operation. The process has worked well for many years, as the power industry moved from coal to oil and gas, then back to coal, and then to nuclear power. A rather sizeable industry has grown up around this system, involving equipment suppliers, engineers, constructors, consultants, and financial institutions. This system will still work for fossil-fueled projects, but there is considerable evidence that it may no longer work for nuclear plants in the United States.

The basic change that may have rendered the product and system obsolete for nuclear plants is the evolution of the regulatory process in the United States. There are, of course, many other problems and complications with political institutions, the media, financial institutions, management practices, and any number of legal difficulties that are created by and feed on the core problem. But these problems could become manageable if the basic problem with the regulatory process were resolved.

The nuclear projects of the late 1950s, the 1960s, and the early 1970s were successful, very successful. The industry could live with and perform under the rules and regulations in effect during those periods. The problem today is that the NRC of the 1980s is not the NRC of the 1960s and the 1970s. The Commission has become so ultraconservative, so bureaucratic, and so demanding in the sheer weight of its procedures and requirements that it is totally impractical for a utility to design and build a nuclear power plant in the traditional manner.

If we are going to have a second generation of nuclear power plants and continue to have the advantages that go with the nuclear option, we are going to have to reform the Nuclear Regulatory Commission to fit the industry or change the industry to fit the NRC. We may in time be able to reshape the regulatory process to make some improvements in the way that the NRC does business. However, I don't really believe that those changes will be significant enough to solve the almost total incompatibility between the regulatory system and the way that we have been building nuclear power plants. Ultimately, we are going to have to change the industry's way of doing business to make it compatible with the regulators.

Change comes hard. People and institutions don't like to give up the old ways. New ideas are not comfortable; they are strange and uncertain. Innovation can be threatening to power structures and vested interests. But change is inevitable. It is all around us. We see it every day, in the automobile industry, in the telecommunications business, in the transportation business, in the computer business, in housing, in health services, in military hardware, and in political institutions. I am convinced that the way in which we finance. design, build, operate, and fuel our nuclear generating plants is just as susceptible to great change as any other element in our society.

Now, I am not going to redesign the product here today, or even begin to cut through all of the questions that relate to the institutional changes that may be necessary. But I have some thoughts on the subject that I would like to share with you.

It seems to me that if we are going to turn things around for the nuclear power industry, then we are going to have to be able to do certain things:

1. We are going to have to cut the average time for a new plant to something under four years. It simply is not feasible to tie up the kinds of money required for one of these projects for twelve years or even six years. More than half of the cost of many of the nuclear plants that will be coming on line in the next few years is tied up in the cost of money during construction.

2. We are going to have to completely standardize plant design, right down to the hinges on the front door. It makes no sense whatsoever to reinvent the wheel with every new project. Now I know that the NSSS vendors have made a lot of progress in standardizing their scope of supply. That is a

good start. But there is no reason why the entire plant can't be a duplicate of a standard design. If we can do this, then the cost of engineering and all of the related procedures and paperwork can be spread over 20, 30, or possibly 40 units and not be the complete burden of a single project. The size of the market in the United States should be large enough to support three or possibly four standard designs at any one time. If we can standardize designs, then we ought to be able to cut the incremental licensing time for each new project to almost zero. The FAA goes through a certification process for each new aircraft design, and that certification then applies to every unit that is manufactured according to that design and specifications. There is no real reason why the NRC cannot do the same thing. These plants will look the same, operate the same, be covered by the same paperwork, the same software, the same training facilities, the same spare parts, and the same operating experience. There is no reason to design a QA program for each new plant. There is no reason to go through the expensive and time-consuming process of writing construction procedures, operating procedures, maintenance procedures, administrative procedures, test procedures, and all the other customized paperwork monsters that accompany each unit today.

3. We will have to stop building each new nuclear plant with a pickup crew of craftsmen who move in and out of the project as the workload cycles. They often do not have relevant experience, and they have to be certified and trained and recertified and retrained as the nature of the work dictates. Productivity and quality would increase significantly with a trained and certified, permanent work force in which each individual or group of individuals could specialize on a discrete unit of work.

It seems to me that, to accomplish these three things, we are going to be forced to go to smaller, factory-fabricated, standardized generating units. Large units can also be built to a standard design (although site characteristics would have a greater impact on the larger units) and cut the costs and times associated with engineering and licensing. But if we are going to significantly cut construction times and improve productivity and quality through factory fabrications, we are almost certainly going to have to limit ourselves to smaller sizes.

Westinghouse pioneered the barge-mounted, factory-built power plant in the 1970s. It was a great concept, and it still is. It is unfortunate that the market for new units collapsed at just about the time the idea was ready to go to sea. There is no question that barges, as an integral part of the plant, can be used as the vehicle to move these units from the factory to the plant site. The Westinghouse design, however, may have been too large to win the market share needed to support a factory operation. Smaller barge-mounted units in the range of 200, 300, or perhaps even 400 megawatts may be the optimum ~~size~~. Units could be mounted on one or possibly two or more barges and moved to the sites, where they would be beached on prepared foundations. In the Gulf Coast area, in the lower Mississippi River valley, and along the Atlantic coast, a large segment of the market could be served by sites that are accessible by water. The same thing is true of the Great Lakes region; most of the Midwest and parts of the Northeast could be served by sites accessible by water.

Factory-assembled modules could also be moved to sites overland or by a combination of water and overland routes. The modules would obviously have to be smaller than those suitable for all-water transportation, and they would require onsite work, something that we want to minimize, but they would represent an improvement over the current practice.

There could be opposition in the industry to smaller units because, with this concept, you lose the advantage of economies-of-scale. It is obvious that if we were to build smaller units in the range of 200 to 400 megawatts in the same way that we have been building the larger 1000- to 1200-megawatt units, we still would have many of the problems that we now have and also lose the advantage of economies-of-scale, but I am not talking about that kind of an operation. With smaller plants assembled from factory-fabricated modules, we ought to be able to cut the time from order to onsite operation to something on the order of three to four years. Remember that some of the early nuclear plants built back in the late 1950s and early 1960s were put into operation in this kind of a time frame. The shorter time alone should cut the total installed cost significantly, perhaps something on the order of 30 percent. The smaller unit size would also permit factory fabrication, with the advantages of greater productivity through improved assembly methods and the use of a permanent work force. These economies could very well overcome the obvious disadvantages of scale.

There could also be other objections. This concept would cut down on the number of players. We could be in a position to use two or three NSSS vendors, but the engineering workload for this kind of a scheme would obviously be significantly lower than that required for one-of-a-kind plants. Opposition could also come from the craft unions, and some utilities might not like the idea of going to a standard plant design that may not accommodate some of their own engineering or operating practices.

The NRC currently has the task of certifying the adequacy of the design, construction, and operation of over 140 commercial nuclear power plants. Each one of these plants is different. It may be different in design, equipment, project management, construction work force, location, or all or any combination of these five elements. The NRC task is formidable. How much easier it would be if, after 1990, all new plants could be divided into only three or possibly four models and each unit of a given model could be designed, equipped, and built exactly the same way in the same facility. The regulatory process would be so much simpler. There would still be problems, but the NRC and real regulatory reform would have a chance.

Today, in this country, plants are almost always the primary responsibility of the owner-operator, the electric utility. The engineers, the constructors, and the equipment and material suppliers sell their goods and services directly to the utility. In some cases, one firm, an engineer-constructor or an engineer, may serve as the project manager, but the ultimate responsibility for the project rests with the utility. By the concept that I have described, the responsibility for the entire project, from the beginning through startup and operation, would rest with one prime contractor. In a competitive market, it is quite conceivable that the utility might not be required to put up any money until the plant is on the line and demonstrates compliance with all specifications. It is even conceivable that a consortium of financial interests might actually own the plant and either lease it to the utility or sell energy to be distributed by the utility.

In scheduling new generating capacity, increments of 200 or 300 megawatts might be much more compatible with actual load growth than one large block of 1000 or 1200 megawatts. A utility could contract for five 200-megawatt units or four 300-megawatt units to be delivered at intervals of one, two, or three years to meet its actual needs. On one site, two, three, or more units could be tied together through one switchyard and operated from one control room. With barge-mounted units, major repairs could be handled by returning the plant to the original factory or to a specially designed overhaul and repair center not unlike the manner in which the Navy services its ships. It is conceivable that, after 40 or 50 years of service, the unit could be refloated, taken out into the middle of the Atlantic, and scuttled in 6000 or more feet of water. The decommissioned plant would be clean in the sense that all fuel, resins, and radioactive liquids and sluiceable solids would have been removed prior to sea burial.

Now, it is my current conviction that, if this concept is to be thoroughly tested, the market and feasibility studies, the proprietary designs, and the many institutional questions have to be the ultimate responsibility of the private sector. However, in the near term, there are some things that this Committee could do to move this concept forward. The nuclear industry in this country is well established. It is large enough and old enough that any significant change in direction will have to overcome a great deal of inertia that is, to some degree, sheltered by vested interests in both the private sector and government. Given this kind of environment, the Committee could be helpful by initiating preliminary studies and research to stimulate and give momentum to the concept of one-design, factory-built nuclear power plant modules.

Thank you for listening to me today.

Mrs. **Lloyd**. Thank you very much, Mr. Jones.

Mr. Webber, please proceed with your testimony.

STATEMENT OF FREDERICK L. WEBBER, EXECUTIVE VICE PRESIDENT, EDISON ELECTRIC INSTITUTE

Mr. **Webber**. Good morning and thank you.

I'll be brief. I'm going to read part of my statement, and thank you for making sure that the entire statement is submitted for the record.

Mrs. **Lloyd**. Yes, it will. Thank you.

Mr. **Webber**. The facts about nuclear power have been obscured recently by widely publicized events which have, unfortunately, distorted the real situation. Normalcy is not news, but the condition of nuclear power is better than many would have you believe. And that is good news for America because nuclear power is not an option for this country; it is an imperative.

A few projects have had serious difficulties, but they total less than 10 percent of the generating capacity of the units now operating and those scheduled for completion.

The fact is that nuclear power in the United States is a success story, notwithstanding the impression left by some and the problems now that a few are experiencing. The facts will dispel the notion that nuclear power has somehow been a failure.

In 1983 some 13 percent of the Nation's electricity was generated by nuclear powerplants. That 13 percent was essential, and we should be grateful for it. Ten years from now that figure should double. At that time only coal will fuel more of our electric power supply.

There are 76 nuclear reactors operating commercially today in the United States. That is more than any other country in the world. Among plants not yet operational, there are 41 units that have construction permits, with definite schedules for completion.

The Congresses and the administrations of the fifties and the sixties were farsighted in providing the impetus that makes all of this possible today. Hopefully, this farsighted approach continues in the eighties, because, as I have said, our development of nuclear power is not a matter of choice. We should be grateful that it is safe, nonpolluting, and economically competitive.

These factors do not make headlines. Little effort has been evident to distinguish among the few companies with serious problems and the great majority which are successfully operating and building nuclear powerplants. We must be careful not to compound the sensationalism by judging all on the basis of a few.

One of the most impressive of nuclear power's attributes is economic. It has saved the country billions of dollars and, if given the chance, will save many more billions. For example, if the electricity supplied by nuclear powerplants between 1974 and 1982 had been provided instead by coal or oil plants, consumers would have paid between $13 billion and $75 billion more, depending on the type of fuel substituted.

Nuclear power's track record is so much better than has been portrayed U.S. commercial reactors have accumulated more than 700 years of operating experience without a single death or injury to the public. This is an unparalleled safety record which warrants, but will not receive, headlines.

Nuclear power will survive and grow for many reasons, not the least of which is necessity. We need the electricity and cannot afford to rely on any single source, whether it be coal or nuclear. For one thing, that is not prudent for national security reasons.

The nuclear power industry is probably the most regulated industry in the world. Opponents of nuclear power—blind in their zeal—have taken every possible advantage of a thoroughly democratic regulatory process. Plants have been blocked and delayed, and the public pays the price.

Along with the Nuclear Regulatory Commission and the Department of Energy, we seek reform of the regulatory process. We do not do so to diminish the public health and safety, but rather to secure a process which concentrates on the substance of safety issues and which is definitive and more predictable.

Where are we today with nuclear power? Despite the strident polemics of the opposition, we are roughly where we have been for the past many years, supplemented by the experience of those years. Nuclear power continues to be a safe, reliable, environmentally acceptable, and an economic source of electricity.

I am tempted to say, "What more could we ask for?" We have the need. We have the resources to meet that need. We should remove the fetters and get on with it. We cannot afford the consequences of a failure to do so.

I'd like to depart from my prepared text now, Madam Chairman, and this is not part of the record, but I'd just like to read a statement in response to what has been I think circumvented or referred to here today.

Mrs. **Lloyd**. Proceed as you wish, Mr. Webber.

Mr. **Webber**. May I do that?

I'd like to answer the basic question, what is being done to revive the nuclear industry and what has to be done today?

First, I would submit to you that we have to get through this difficult period of completing those nuclear plants that are currently under construction, all of which were ordered prior to 1974. This requires detailed adherence by the utilities to the Federal rules, to quality assurance, and to verification of the designs and construction that has been outlined.

Substantial funding is needed to complete these projects. Beyond that, we must achieve a predictable licensing process. We must have standard plans designs, and we must have a means whereby the suppliers and the constructors of the facilities are participants in sharing the risks and accept some responsibility to complete these facilities within a predictable time period and at a predictable cost, and I think this is what Dr. Lester was referring to earlier.

The current open-end approach where the utility and its ratepayers are assuming essentially all of the risks is unacceptable. There is a real need on the part of utilities to have new approaches developed for the procurement and delivery of nuclear powerplants. However, it will be up to the supplier industry to bring forth a product that can be delivered in a predictable manner and to stand behind it. Utilities are geared to produce and deliver electricity, and they want to purchase facilities on a predictable basis that can serve the needs of the public in an efficient manner.

Thank you.

[The prepared statement of Mr. Webber follows:]

PREPARED STATEMENT OF FREDERICK L. WEBBER, EXECUTIVE VICE PRESIDENT, EDISON ELECTRIC INSTITUTE

NUCLEAR POWER TODAY

The facts about nuclear power have been obscured recently by widely publicized events which have unfortunately distorted the real situation. Normalcy is not news. But the condition of nuclear power is better than many would have you believe. And that is good news for America because nuclear power is not an option for this country, it is an imperative.

A few projects have had serious difficulties, but they total less than ten percent of the generating capacity of the units now operating and those scheduled for completion.

The fact is that nuclear power in the United States is a success story, notwithstanding the impression left by some. The facts will dispel the notion that nuclear power has somehow been a failure.

In 1983, some 13 percent of the nation's electricity was generated by nuclear power plants. That 13 percent was essential and we should be grateful for it. Ten years from now, that figure should double. At that time, only coal will fuel more of our electric power supply.

There are 76 nuclear reactors operating today in the United States. That is more than any other country in the world. Among plants not yet operational, there are 41 units that have construction permits, with definite schedules for completion. The Congresses and the Administrations of the 1950's and 1960's were farsighted in providing the impetus that makes all of this possible today. Hopefully, this farsighted approach continues in the 1980's, because as I have said, our development of nuclear power is not a matter of choice. We should be grateful that it is safe, non-polluting and economically competitive.

These factors do not make headlines. Little effort has been evident to distinguish among the few companies with serious problems and the great majority which are successfully operating and building nuclear plants. We must be careful not to compound the sensationalism by judging all on the basis of a few.

One of the most impressive of nuclear power's attributes is economic. It has saved the country billions of dollars and, if given the chance will save many more billions. For example, if the electricity supplied by nuclear plants between 1974 and 1982 had been provided instead by coal or oil plants, consumers would have paid between $13 billion and $75 billion more, depending on the type of fuel substituted.

Nuclear power's track record is so much better than has been portrayed. U.S. commercial reactors have accumulated more than 700 years of operating experience without a single death or injury to the public. This is an unparallelled safety record which warrants -- but will not receive -- headlines.

Nuclear power will survive and grow for many reasons, not the least of which is necessity. We need the electricity and cannot afford to rely on any single source, whether it be coal or nuclear. For one thing, that is not prudent for national security reasons.

The nuclear power industry is probably the most regulated industry in the world. Opponents of nuclear power -- blind in their zeal -- have taken every possible advantage of a thoroughly democratic regulatory process. Plants have been blocked and delayed, and the public pays the price.

Along with the Nuclear Regulatory Commission and the Department of Energy, we seek reform of the nuclear regulatory process. We do so not to diminish the public health and safety, but rather to secure a process which concentrates on the substance of safety issues and which is definitive and more predictable.

Where are we today with nuclear power? Despite the strident polemics of the opposition, we are roughly where we have been for the past many years, supplemented by the experience of those years. Nuclear power continues to be a safe, reliable, environmentally acceptable, and an economic source of electricity.

I am tempted to say -- "What more could we ask for?" We have the need. We have the resources to meet that need. We should remove the fetters and get on with it. We cannot afford the consequences of a failure to do so.

Other Nuclear Elements

Now I will turn to a few of the other nuclear items of the DOE Fiscal Year 1985 Budget Request and several items of specific interest to the Subcommittee.

Three Mile Island Activities - The cleanup of TMI-2 must and will be achieved. All of the contaminated water has been processed through chemical filters to remove the radioactivity, and the surfaces are being decontaminated inside of the containment building. The next major activity is the removal of the head from the reactor to permit access to the damaged fuel. DOE assistance on this effort is essential and we urge full support for, or expansion of, this budget item.

Nuclear Licensing Process Improvements - The nuclear licensing process must be changed to achieve earlier public participation, remove uncertainties in the process, provide hearings on those issues that truly affect public health and safety, encourage the use of standardized plant designs and perhaps the most important element is to create a sensible, systematic and documented approach to the imposition of backfitting. A careful examination of the licensing and regulatory system provides ample evidence that it evolved, and continues to evolve, in a largely undisciplined manner. This is inconsistent with the large and still growing number of nuclear power plants. Therefore, the primary objective of regulatory reform should be, consistent with the health and safety of the public, to eliminate the inefficiencies in the current process. Such action will assure the continued safety of the public.

As discussed earlier, our country's economy will grow, and so will the demand for more electricity. This linkage is vividly evident over the past few years. While total energy consumption in the nation has gone down, electricity consumption continues to grow in a manner that is related to economic growth. This growth can be partially accommodated by further conservation, load management and the use of renewable energy resources. But we will need new capacity and only two fuels, coal and uranium, are available for major expansion. Relying only on one of these would be foolhardy. Licensing reform is essential to permit both fuel options to be available in the future.

Several specific licensing issues are of immediate concern to us:

- One large nuclear plant will be completed and waiting for an NRC approval to load fuel this year while the Hearing Board continues its scheduled deliberation on the plant that extends several months beyond the time that an operating license is needed. This is an obvious case of a need for NRC permission to issue a temporary operating license.

- Another situation is the continued refusal of a locality and the state to cooperate in the preparation of an effective off-site emergency response plan in the vicinity of a nuclear plant. They, in effect, have achieved a veto authority over safety aspects of a nuclear power plant operation, which has been held as a Federally pre-empted authority since the passage of the Atomic Energy Act of 1954. A means is needed to overcome the outright refusal to cooperate by a locality or a state.

o In still another situation, the NRC appears to be taking an unusual and what appears to be an inappropriate approach to satisfy Section 306 of the Nuclear Waste Policy Act of 1982. This section of the legislation calls for greater emphasis on the training of nuclear power plant operators, and all or part of it could be satisfied with regulatory guidelines. NRC appears to be expanding on this and developing new rules and regulations for nearly all persons working at a nuclear power plant. This flies in the face of the utility industry efforts in this area. Prior to the accident at TMI-2, the NRC regulated training only for reactor operators. Then the Institute of Nuclear Power Operations (INPO), was set up by the industry with one of its primary functions to address the area of training for key nuclear plant positions. The industry, through INPO, has taken initiative in establishing training programs for other nuclear plant positions, as well as licensed operators. Considerable progress and momentum has been achieved. We believe that INPO is doing a credible job of industry self-regulation in the training area. New NRC regulations in this area could undermine the INPO/industry initiative. This appears to be a direct step of over regulation by NRC, beyond that called for in the legislation, that is a disincentive for further industry efforts of self improvement through organizations like INPO.

Breeder Reactor Systems - Breeder reactors continue to represent the best apparent technology to satisfy the long-term need of assured electricity supply that can be available for many centuries. Earlier projections of when this technology would be needed were overly optimistic and there is time to pursue the important matters that will permit this technology to be used efficiently. Now that Congress has withdrawn support for the Clinch River Breeder Reactor demonstration project, the DOE breeder program should be directed toward those research and development programs that have the greatest potential payoff. Funds should be made available and concentrated on those tasks that will expand our technological base on breeder reactors and the accompanying fuel cycle.

Convertor Reactor Systems - Light-water reactors being used successfully to produce electricity are converter reactors. The continued use of these reactors is vital to the financial health of the nation. Programs are needed to overcome the unnecessarily burdensome institutional, financial, technical, and regulatory barriers in this area. Also, many utilities continue to support the High Temperature Gas Reactor (HTGR) concept and believe that it should be pursued as a reasonable alternative technology to today's light-water reactors. These utilities support the development of HTGR technology both financially and with managerial expertise through the Gas Cooled Reactor Associates (GCRA). Continued Government cooperation and financial support are vital to the success of the joint effort now underway to determine if the HTGR will be sufficiently attractive to achieve commercial acceptability.

Mrs. LLOYD. Thank you very much, Mr. Webber. I appreciate your remarks.

"If electricity supplied by nuclear plants between 1974 and 1982 had been provided instead of coal or oil plants, consumers would have paid between $13 billion and $75 billion more, depending on the type of fuel substitute." Does this include the cost of the plants or is this the fuel?

Mr. WEBBER. This is primarily the fuel cost, but they have to work it into the cost of the plant as well, but it's primarily fuel.

Mrs. LLOYD. I think it's also worthy of note that we repeat that our reactors have accumulated more than 700 years of operating experience without a single death or injury to the public. This is an unparalleled safety record that, unfortunately, does not receive headlines.

Directing the fission R&D program toward the large, gigawatt size may not be appropriate, you gentlemen have stated. I think that smaller-sized powerplants in the 100-to-300-megawatt range may offer a better return on capital investment and at the same time have greater inherent safety features.

I'll direct this to you, Dr. Lester: what are the advantages of redirecting our R&D efforts toward the smaller—I'm not especially referring to the inherently safer reactors but the smaller—rather than large powerplant designs?

Dr. LESTER. I think you have already alluded to some of the advantages that may be associated with smaller reactors, as has in fact Mr. Jones before me.

The advantages that I perceive here include the opportunity for design simplification, opportunities which I don't believe have been fully exploited or fully explored even to this point in the area of light water reactor design.

Smaller reactors also offer opportunities for shorter construction lead times, reduced utility financial exposure, and better matching of the capacity additions the utilities must make with utility load growth, particularly in an era in which utility demand is growing significantly more slowly than it has done in the past.

Mrs. **Lloyd.** Thank you very much.

Dr. Weinberg, would you like to comment on this redirection toward the smaller, rather than the larger, powerplant designs for our research and development efforts?

Dr. **Weinberg.** I can see a good deal of merit in hedging one's bets by building smaller reactors and having, as Dr. Lester points out, smaller financial exposure. However, I think one has to look at the situation from the following point of view—that the latest polls, as I understand it, show that more than 50 percent of the American public no longer likes nuclear energy. It's not entirely apparent to me that focusing on smaller reactors without the strongest concern for inherent safety is going to turn that around, and this is the issue. It is not that we and the nuclear community don't think that reactors are adequately safe. We do think that they're adequately safe. But for some reason, the American public doesn't quite believe us, and it is essential that we turn that around.

I think that David Lilienthal was really correct, that you have to change something and change it in a very clear way, in a way that the public sees as a real change. It's not clear to me that simply building smaller reactors without stressing very, very heavily the fact that they are safer reactors or more forgiving reactors will really accomplish what it is that we all feel must be accomplished.

I can't at all disagree with what Mr. Webber says, that nuclear energy has been a marvelous success, if viewed from what we in the nuclear community regard as a rational point of view, but that isn't the issue. The issue is that the public doesn't agree with us, and we must change that or we won't have nuclear energy.

I fully agree that small is probably rather beautiful, but I think safe is even more beautiful.

Mrs. **Lloyd.** Well, Dr. Weinberg, let's go back to the remarks that Mr. Webber said. Yes, we do have an excellent track record. Yes, we do have safe plants. We all agree on this, but at the same time we've also said we need to proceed to the smaller reactor, which is going to have a greater success story.

This brings up the point that I wanted us also to agree on. Even with an inherently safe reactor, a low-cost reactor, we're still going to have to do the same job of trying to sell our product that we should have done 10 years ago?

Dr. **Weinberg.** I agree.

Mrs. **Lloyd.** Would you like to comment on that, Mr. Webber?

Mr. **Webber.** I'd like to talk about this so-called inherently safe reactor concept. I'm very, very concerned about it.

Much publicity has been generated during the past couple of weeks on the so-called inherently safe reactor. This was discussed in the budget request that was sent to Congress by the President last week. It was the subject of a news media briefing on Monday of this week by the Office of Technology Assessment, and it's being discussed today and tomorrow in hearings before several subcommittees in the House. I think half my staff is up here this week testifying.

Now while many words are being, and will continue to be, generated on this subject, my primary reaction is that the term is misleading. Everyone who has a new reactor concept for which he would like to have the Federal Government fund its development is now using this buzz phrase "inherently safe reactor."

New concepts of gas-cooled reactors, water-cooled reactors, and fast breeder reactors are being billed under this phrase. If you think about it for a second, anytime you're going to have nuclear fission to provide heat to make electricity, you must contain it somehow. That is what we are doing with commercial reactors today.

While we have never succeeded in determining how safe is safe enough for the nuclear reactor, today's reactors with all their redundant safety features now are inherently safe.

What is the perceived incremental added safety measure provided by the new concept that allows them to fall under this new sexy phrase, if you will?

Yes, we are interested in improved safety, and you're absolutely right, Madam Chairman, we have to convince the public that we are interested in safety, and somehow we have failed to do that, for a host of reasons.

Yes, we are interested in improved safety, but, no, we do not believe these new concepts with new clothes will be perceived by the public as a solution to their anxieties about nuclear energy. This phrase is simply misleading.

Mrs. **LLOYD**. Dr. Weinberg, would you like to comment on Mr. Webber's statement?

Dr. **WEINBERG**. I don't really think the phrase is misleading, if one understands what we mean by the words "inherently safe."

We agree that light water reactors are extremely safe, as judged by probablistic risk assessment, as judged by the history. On the other hand, the safety of existing reactors depends upon the intervention of mechanical and electronic devices. By "inherently safe reactors," we mean reactors whose safety does not depend upon the intervention of mechanical and electronic devices. It's as simple as that.

And Mr. Webber may be entirely correct that even a reactor which the technical community says is inherently safe in the sense that it does not require intervention would not be perceived by the public as being inherently safe. He may be entirely correct, in which case there's not very much point in trying to develop things of that sort.

I believe that as an R&D effort it is of great importance over the long term to know whether it is possible to have a reactor whose safety depends not on the intervention of mechanical or electronic devices, but on laws of physics and chemistry. That's what we mean by inherently safe.

Mrs. **LLOYD**. Mr. Jones, it's your turn.

Mr. **JONES**. Yes. We have a problem with the pubiic. I don't think there's any question about that, but I don't think that safety is necessary the primary issue.

Nuclear power is in the papers, in the magazines, in the news everyday these days, and safety is not the current issue. The current issue is financial problems, overruns, schedule delays, equipment problems, and those kind of things.

Regardless of what media, magazine, or newspaper you're talking about, those are the things that have been in the newspaper very strongly for the last year or so.

And I agree with Mr. Webber—if we come up with a new design and stress that it's more safe somehow than the ones we already have, I don't think that the public, if that's their problem, will believe us. I think the real problem that the industry has today is delivering the product, which is the powerplant, on time for a reasonable cost and to stay out of the news, and that a new concept at this time, which will take years to develop, is not necessarily the primary thing we should be going after in the priority issue here.

Mrs. **Lloyd**. Well, no new large plants have been ordered for how many years, Fred?

Mr. **Webber**. Well, a good half dozen, anyway, and I don't know of any nuclear, or I should say electric utility executive that is even thinking of ordering a new plant at this point in time.

Mrs. **Lloyd**. We're at the point that the chairman and I tried to put into play yesterday when we had our press conference on the OTA report, that we need to be moving forward with a reactor that the utilities can afford, not only can afford but will buy. That was one of the main emphases that we had.

Mr. Jones?

Mr. **Jones**. Madam Chairman, I think when you come right down to it, the basic issue here is the question, will the utility managements in this country order new nuclear powerplants? And the thing that will keep them from doing that is not the safety issue, because they believe that the nuclear powerplant; it has an excellent record. If they don't order new powerplants in the future, it's because they're financially risky. That's the basic issue. It takes too long for them to put these plants on the line, and they're too much of an administrative headache.

The safety issue is not the big issue with the people that are ordering the plants. It's financial problems and the mechanism we have for bringing the products to the marketplace.

Mrs. **Lloyd**. Well, I could keep this going all morning with you distinguished gentlemen, but our time has more than expired.

Mr. Chandler?

Mr. **Chandler**. Thank you, Madam Chairman.

Mr. Jones, you said something that really caught my ear. I represent the State of Washington, and if you went out there to my district, which I think is a well-educated, enlightened group of people, and suggested that we ought to develop more nuclear power, I don't think that they would say no out of fear; they would say no because there were five Washington public power supply system plants started in response to what was projected to be a demand which didn't begin to develop. The construction was managed by people who had absolutely no business building one nuclear powerplant, let alone five. They were constructed by people who couldn't stay on schedule.

The bonds—the market for money went out of sight, unpredictably on and on and on. And when you say what the public would like to see is a nuclear powerplant that gets finished on time, within budget, and supplies the correct amount of energy, or whatever else you said, you really strike a responsive cord with me.

The point that you made about—I think you were suggesting a small, prefabricated, constructed-in-a-factory environment powerplant. Are you suggesting that—and you said that you thought that the committee, the Congress, could be of assistance in developing that concept. Do you think we ought to build a prototype, or what exactly are you suggesting that we do?

Mr. JONES. Let me say something. I'd like to answer that, but let me say something first.

The problem that the people had in the State of Washington is because they had to plan 10 years in advance or 12 years in advance, and I don't know of anybody, really, with all due respect to people, that is smart enough to look 12 years down the road and know what the cost of production is going to be, know what inflation rates are, know what interest rates are going to be, know what regulations are going to be, your competitive fuels are going to be. We have to do these things in a shorter length of time. We have to do them in 3 to 4 years.

We can build nuclear powerplants in 4 years. The first nuclear powerplant in this country was the Shippingport plant, and it was built in 3 years and 4 months. That was the first one. Albeit, it didn't have a lot of help from other organizations, Government, and what have you, but, nevertheless, it was done. And the plants after that were also done in 3- and 4-to-5-year intervals. So we can do that.

I think one of the major priorities is to build plants in a shorter length of time, and we can do that principally with smaller plants. It's easier to do it with smaller plants.

Now you can do that—you can build smaller plants in the field the way we have been building plants in the field, but if we did that, we'd have many of the same problems that we have today. Every plant would be different, and, therefore, the NRC would have to go through long and drawn-out regulatory and licensing procedures for every plant, which would complicate the process.

The FAA licenses a new aircraft design—"certifies" it, I believe is the word—and then every duplicate of that aircraft thereafter is automatically certified if it is built to the specifications and design.

One of the reasons we ought to go to standard design is maybe the NRC could also adapt that principle. To do it, however, it's probably more convenient to do it in a factory environment because then you can guarantee the NRC and the public that it is built to design and the specifications more easily. You can get higher productivity, reduced man-hours. You can get higher quality. You can turn it around faster and overcome some of the disadvantages of economy of scale that a smaller plant has.

Mr. CHANDLER. My question was, what role does the Congress play in this? Do you think we should fund a prototype or——

Mr. JONES. No.

Mr. CHANDLER. What are you suggesting we do?

Mr. JONES. No, no. I do believe, by the way, that the Japanese Government has funded or certainly contributed to prototype designs, but I don't think that's necessary here in the States. I think the private sector is strong enough to take the lead if we can get a little bit of momentum. To get that momentum, I think that this committee could initiate some preliminary studies and preliminary research that would give some validity to the idea of moving factory fabricated modules around the country on the waterways and the highways, and what have you, and that in fact we could put a plant together that way.

Mr. **Chandler**. I'd like to ask all the panelists, who have been excellent today, and my compliments to each of you—what barriers, technical, institutional, organizational, or whatever else, do you see to this concept that Mr. Jones is talking about?

Dr. Lester, you were particularly harsh about that, I think, suggesting that there are barriers to our achieving this smaller, prefabricated, standardized design plant.

Dr. **Lester**. Well, I think that the most evident barrier to progress in this direction is that inevitably it is going to require some fairly substantial upfront capital investment in constructing the sorts of facilities that would produce these plants. And in the absence of a well-defined market, I think the primary obstacle that I would identify in this particular area is that of making the necessary investments available.

Mr. **Jones**. I think the only real barrier is the question, do we have a market or do we not have a market. I think that if we can—if the vendors, the major vendors, can be assured that there is a market for 200-, 300-, and 400-megawatt reactors, built on barges or built in modules in factories and shipped to plants, or in some fashion like that, that I think they're strong enough and innovative and creative enough to move out on their own.

At the moment, however, it is very difficult for anybody in business to look ahead and assure themselves that there's going to be a market. There's too many factors—regulatory, economic, and otherwise—floating around for them to take that kind of a jump. Westinghouse took that jump a while back with their large offshore project, which I think was a very good idea. It may have been a little bit too large for the total marketplace, but basically I think it was a good idea. And they've had a problem with the shrinking market at the time it was ready to go to sea, which was unfortunate.

Some people went to bat one time and invested a lot of money in a reprocessing facility down in South Carolina, and they cut off. So the industry is a little wary of looking off into the future and saying they're going to take all the risk, when they don't know what regulatory and economic and political factors will do to their market.

Mr. **Webber**. I endorse all that's been said on this subject so far. I'd like to make a couple of additions.

One, having gone to France a year ago and seen firsthand that successful nuclear program, I kept asking myself why. And the basic, underlying reason why, or the answer to that question really is that France has no choice. It doesn't have the options that we have here. We have a lot of coal, and we have some renewables that we'd like to expand and some other technologies that we would like to develop.

I think one of the greatest barriers to further development of nuclear power revolves around this perception that we really do have other options and that we don't need to go to nuclear. Somehow, some way we've got to convince the American public that nuclear's got to be part of the proposition, part of the equation. We'd like to think it ought to be a third of the equation in terms of electricity production. Good Lord, you know what kind of problems we have burning coal, especially high-sulfur coal burning, and I don't want to raise the acid rain debate here, but it's not without its problems.

We feel, again, that in an electricity mix you've got to have something like nuclear there to produce power economically.

The second thing is the confrontational mode that we find ourselves in vis-a-vis the Federal Government. We've got to stop that. We've got to be partners with the Federal Government in this regulatory business, if you will, not adversaries. Again, you go to France, you go to other countries where there's a national will to get on with it, and you have successful nuclear programs.

And, by the way, if you want to bring in the size argument, I'm worried that the drift of this conversation here today is toward this business of let's come up with a 200-, 300-megawatt unit; maybe that's the way to go. Let's be careful. We want to focus on safety issues, et cetera, but we've got to also focus on economic issues, and those economics have got to be worked out before we go to the standardization design and decide that 300-megawatt units are really the size to go. I'm very nervous about that. I don't say I don't endorse it, but I think the economics have to be examined very, very closely, indeed.

Finally, the other barrier is that this country feels that its energy security is intact. And you and I know, Congressman, that's not true. In a matter of hours we could have our energy security shattered by the closing of a certain strait overseas. If we had our oil cut off from foreign sources, I'll guarantee you that those who were ambivalent about nuclear power today would be singing or whistling a different tune, and that worries me more than anything.

Mr. CHANDLER. I've always found it ironic that the same person that would come here and demand an answer to the acid rain question would demonstrate at the gates of a nuclear powerplant and light up a cigarette when they got in the car on the way home.

Mr. WEBBER. Yes, sir.

Mr. CHANDLER. I agree with you. Thank you.

Mrs. LLOYD. Thank you very much, Mr. Chandler.

Mr. Walker?

Mr. Walker is ranking minority member of this subcommittee, and he is also a very valuable member of the committee, as well as Mr. Chandler.

We're glad you're here today, Mr. Walker.

Mr. WALKER. Thank you, Madam Chairman.

And since I was not able to be here at the opening of the hearing, I'm going to begin my time here with a brief statement and then go to a couple of questions.

This morning we commence our review of the budget proposed by President Reagan to the Department of Energy in the coming fiscal year. It's the start of a long process in which this committee, and later the House of Representatives, will examine and weigh the budget proposal for fiscal year 1985.

The secret to a successful budget process is that it must be adversarial each step along the way. I intend to view the administration's proposal with a very critical eye in hopes that the program which Congress finally approves will represent the best possible allocation of our increasingly scarce fiscal resources.

There are several issues which will be of great interest to the committee this year. We're paying particular attention this year toward focusing future nuclear research within the Department of Energy on inherently safe reactors. It is obvious that unless we move quickly to reassess our nuclear future that the economics of this current marketplace will mitigate against a nuclear future.

The last decade has seen the cancellation of numerous nuclear plants, due mainly to cost concerns. We have seen a constant increase in the problems associated with licensing the new facilities, and there are increasing concerns both within and outside the nuclear industry that further licensing delays in that future could drive the costs of the nuclear energy far above the level where it is competitive.

In the past we have operated in the nuclear area in this country in a way that is exactly opposite to the methods which have made America a world leader in high technology. Each new reactor was custom designed and each was different from all other reactors. Because of this, each and every reactor had to go through a licensing process from start to finish.

Can you imagine the American Airlines going to Boeing and saying, "We'd like that new jumbo transport you built for United, and we want you to build one for us, but let's sit down and design one from the ground up because we don't want to fly the same routes that they do"? That would not only not make any sense, but the board of directors would fire the idiot who proposed such a move.

We think it is high time that we move toward developing a new modular reactor plant that would be standardized, so that we would not have to reinvent the wheel for each new order, so that the basic design could be licensed as we now license airframes.

We also hope that these new designs would result in reactors which would be so safe that in the case of an accident such as the one at Three Mile Island the reactor would either shut down automatically or would allow sufficient time for operators to correct the problem without damage to the reactor itself. Such design features are not only possible, but they already exist.

For example, the high temperature gas-cooled reactor known as HTGR is so slow to react in an emergency, the comparison would be at Three Mile Island, where the operator had only 60 seconds in which to react to the emergency before damage occurred, an operator at an HTGR would have at least 24 hours. We think that this is clearly an area that should be one of the highest research priorities at the Department of Energy.

I have a strong interest in the problem of the cleanup at Three Mile Island, and expect that this subcommittee and the full committee will take a very close look at that this year. While TMI is not in my congressional district, I, along with all other Pennsylvanians, have a strong interest in seeing that the cleanup is completed as quickly as possible and as safely as possible.

I'm also deeply concerned as to how the integrity issues which have been raised repeatedly concerning the management of TMI will affect the research which this committee has authorized on the island.

Another issue which I believe we will want to take another look at this year will be the space reactor program, which is a joint effort among the Department of Energy, the Department of Defense, and the National Aeronautics and Space Administration. This program has been a fairly low priority item, but with the announcement by the President this country will move into space with a permanent space station, the need for a greatly enhanced power supply becomes much more immediate.

Finally, I want to state that last year the Congress determined to end the Clinch River breeder reactor project. During the course of that debate I stated that I fully supported the base breeder program. I still feel strongly that America must move forward in the area of breeder technology.

Chairman Lloyd and I have already discussed this program in considerable detail, and we will be examining it in hopes of finding bipartisan cooperation.

We are pleased to see a budget request that has stressed long-term basic and applied research. In 1974 the total Federal commitment to energy programs stood at $1.2 billion. This year President Reagan has requested $8.8 billion in energy-related outlays in fiscal year 1985, of which $3.1 billion will be on budget. In fact, the administration has proposed a 16-percent increase in energy-related general science research for fiscal year 1985.

While we in the Congress will undoubtedly see fit to make some modifications to the budget as proposed, I expect that this committee will be strongly supportive of DOE research and development this year.

Now, Madam Chairman, if I could ask just a couple of questions, please.

First of all, of Mr. Webber: Can you give me some idea at this point what the contribution level is that EEI now has pledged for TMI cleanup?

Mr. **Webber**. As you know, our goal is to come up with $100 million minimum from our investor-owned electric utilities companies. That's part of the so-called Thornburgh cost-sharing plan, whereby the Federal Government contributes and the States contribute, and obviously the customers of GPU contribute. We're about two-thirds of the way there.

One of the reasons why we've been slow on the draw, if you will, on this is because of the pending IRS ruling: Would these contributions be tax deductible? In the last few weeks that ruling has come in two parts, one for a coal company and one for a nuclear company. In effect, we got the ruling we wanted, and the IRS said, yes, they are tax deductible, so now our companies can go back to their boards with a proposal to make contributions to help clean up Three Mile Island, and I am cautiously optimistic we'll make the $100 million goal. We need more time, but we're going to attempt to do it, yes.

Mr. **Walker**. Of course, a number of us pushed pretty hard to get that favorable IRS ruling, and one of the reasons why we did that was in hopes that there would be a fairly immediate reaction on the part of the utilities toward coming up with a contribution, because we had heard all the way along that that was, in fact, a major problem. And now with the favorable ruling, it doesn't sound to me as though you've gotten very far, even though that ruling has now been around for about 6 to 8 weeks.

Mr. **Webber**. Well, Congressman, with all due respect, in most cases the utility chief executive officer must consult with his board in a formal meeting before that contribution is forthcoming. And, second, a lot of collaboration with the public utility commission at the State level has to be executed. Remember, there are commissions throughout the country that take exception to any utility, whether they take it below or above the line, contributing to the cleanup of Three Mile Island because they think that's your problem, not theirs. We obviously respectfully disagree with them. We think it's an industry problem, but it is not as easy as it appears.

Our companies are moving to deal with their boards and their commissions, and I suspect that we'll get—if we don't make the $100 million goal, we'll certainly get very close to it.

Mr. **Walker**. Well, the one problem I have with that scenario is the fact that it had been my understanding in conversations that a lot of those kinds of discussions had been taking place all the way along; that we had been trying to clear the decks with regard to the PUC's around the country, so that, if we got a favorable IRS ruling, that a lot of those decks would be cleared; that the boards of directors, and so on, had been consulted with; and that basically the decision had been made by a lot of companies that if, in fact, we were allowed to make this a tax writeoff, that we would be willing to go.

And what I'm concerned about is the fact that the cleanup money is needed now. We have just recently gotten a rescission notice from the Department of Energy with regard to this year's funding levels for Three Mile Island because we have not been able to move fast enough there to be able to utilize DOE funding that has been made available for the cleanup process.

Now if all parties don't come through with the amounts of money that are necessary for that cleanup to take place, what happens is that the cleanup gets slowed down, the Federal money trickles in at a rate less than what had been approved, and we've got ourselves a big problem there.

And I'd like to think that we are not reacting to this as one of the things that can be put on the back burner, but rather this is something which is of immediate concern.

Do you have some idea as to when we might expect some kind of idea as to when the $100 million is going to be come up with? I mean, I'm going to assume that you're going to get the $100 million. I can't imagine that the industry would not come up with the money at this point.

Mr. **Webber**. I am not going to make any predictions. I learned a long time ago in this town never to do that.

I will say to you that I share your frustration, I share your concern. As representatives of GPU will tell you, our association has been very aggressive in getting our member companies to belly up, if you will, belly up to the bar, I should say. I'd better be careful with that terminology.

Mr. **Walker**. Yes, that's bad terminology.

Mr. **Webber**. That's right, especially in this day and age. I cannot predict the actions of the boards or the commissions. I will say to you, again, there are some commissions that would take serious exception, that look at the kilowatt hour rates that the customers of GPU pay and they're half of what their customers pay, so they scratch their heads and say, "Why should the customers in this part of California, or wherever, or Arizona pay for the cleanup of Three Mile Island?"

The staff of the Edison Institute continues to lecture them and say, "It is a much bigger problem than that, and you ought to come in." I've told Governor Thornburgh repeatedly that I thought his plan was a good one and that we would try to carry our fair share, but I am not going to predict; I dare not.

Mr. **Walker**. Can we establish something whereby this subcommittee would get some regular progress reports, say a monthly progress report, as to how we're coming along on getting that $100 million together?

Mr. **Webber**. I'd be more than happy to do that and welcome your interest.

Mr. **Walker**. I thank you.

One question for Mr. Jones as well: You state that nuclear projects in the late fifties, 1960's, and early seventies were very successful. Why, then, in the more recent installations have we experienced things like cracked welds, inadequate peripheral equipment, faulty electrical relays? What's gone wrong in the more recent installation?

Mr. **Jones**. Well, first I would say that powerplants have been around for a long time. They go back many, many decades, and steam generators and pumps and turbines and all other pieces of equipment in those powerplants have had similar problems that we have today. The industry has lived with them and improved upon them, maintained them and repaired them, taken the plants out, fixed them up, put them back together again, and they never made the newspapers and nobody ever knew they had any problems. But now, today, every time some valve or some pipe or some piece of equipment in a nuclear powerplant has a rather conventional kind of problem, it's all over the world; it's in the newspapers and it's on the television.

These problems are part of doing business. I'm not saying they can't make improvements; I think they will. But those kinds of problems have been around for a long, long time.

We have automobiles every day, and we come up with new ones and everybody buys them and is in love with them, and they have problems, and they have problems with airplanes and ships and even satellites in the sky that don't work always the way they're supposed to work.

Mr. **Walker**. Well, but how do you get reversed blueprints like the thing that happened at Diablo Canyon?

Mr. **Jones**. I can't answer that one. I wasn't there. I don't know the details.

Mr. **Walker**. I mean, you know, but those are the kinds of concerns. We sit here and we have to deal with the overall issues on these things. It makes it extremely difficult for us when those kinds of problems that would seem to be almost basic things come back to haunt us as we try to pursue an aggressive policy.

Mr. **Jones**. I can't speak in detail to that particular problem, but I will go back—as I said earlier, and I think you also said, that if you build duplicate copies of something, whether it's an automobile or an airplane, or what it is, and you do it with the same people who have done it the day before and will do it the day after, you can eliminate a lot of those problems.

Mr. **Walker**. Which we already do, for instance, in the Navy's nuclear program, which we could apply to commercial.

I thank you, Madam Chairman.

Mrs. **Lloyd**. Thank you very much, Mr. Walker.

We have really exceeded our time for the first panel, but you've been such a delightful and knowledgeable panel that it's been very tempting to go on and on.

But, very quickly, do you believe—I'm just going to ask all of you this question—that the nuclear R&D program has a proper distribution of resources when we have $308 million in breeder development and less than $50 million in all other advanced reactors?

Dr. **Weinberg**. I think my view on the matter is quite clear. I have consistently been a great proponent of breeder development, and I think breeder development should continue. But I also believe that—and this I agree pretty well with Mr. Lester—that the business is in a state of crisis, and one really ought to reexamine the entire program from the point of view of it's not that we want the very best thing for 50, 75, or 100 years from now, but it's that we want to make sure that the patient survives until then. From that point of view, I think some readjustment of priorities is in order.

Mrs. **Lloyd**. For the record, your comments, Dr. Lester.

Dr. **Lester**. I would just essentially repeat what I said in my remarks, which was—what I implied in my remarks, which was that in my view the current distribution of resources doesn't really reflect the sorts of priorities that we now have in the nuclear power industry.

Mrs. **Lloyd**. Mr. Jones?

Mr. **Jones**. I really——

Mrs. **Lloyd**. We're having microphone troubles.

Mr. **Jones**. All I think I can really add is that I think that the total amount of money that's available for breeder research and other reactors is probably lower than it should be considering the importance of power and electricity to the standard of living in the United States and the rest of the world.

Mrs. **Lloyd**. Fred?

Mr. **Webber**. Well, I think that we need more money in those programs. I'm intrigued with the high temperature gas-cooled reactor program, which, as you know, is supported by many of our utilities and has been a cooperative program as far as the Government and the industry are concerned.

And, second, as far as breeder reactors are concerned, we continue to think they represent the best of current technology to satify the long-term need of electricity supply, and we're looking now centuries ahead. I agree we can't look 10 years ahead, and here I am looking at another century, but our best thoughts and scientists tell us that that's the way to go.

Clinch River has been erased, if you will, so we think that the DOE breeder program should be erected for its R&D programs that have the greatest potential payoff. And I don't think that's too much money to put into a base breeder program. That's not a personal opinion, incidentally; that's an institute opinion. But we feel very strongly that funds have to be made available and concentrated on tests that will expand our technological base on breeders and the accompanying fuel cycle.

Mrs. **Lloyd**. Thank you very much.

Thank you, Dr. Weinberg, Dr. Lester, Mr. Jones, and Mr. Webber.

Please welcome our next panelist, Dr. Ersel Evans, who is technical director at Hanford Engineering Development Laboratory; Mr. Donald Trauger, associate director for nuclear and energy technologies at the Oak Ridge National Laboratory; as well as Dr. Paul Kasten, who's also from the Oak Ridge National Laboratory.

We welcome you, gentlemen, to our hearing this morning.

We do have your complete statements, so all of you may proceed as you wish to summarize or to maybe move into other areas, but your prepared statements will all be made a part of the record.

Dr. Evans, you are our first panelist. Please proceed.

STATEMENT OF DR. ERSEL A. EVANS, TECHNICAL DIRECTOR, HANFORD ENGINEERING DEVELOPMENT LABORATORY, WESTINGHOUSE HANFORD CO., RICHLAND, WASH.

Dr. **Evans**. Thank you, Madam Chairman.

I'm lucky to start the discussion of reactors which are both small and, we hope, very safe.

The experimental breeder EBR–II has done a phenomenal job for two decades in testing a wide range of fuels and materials under the most extreme conditions, including operation with deliberately defected fuels.

More recently, at Hanford, the Fast Flux Test Facility, the world's most advanced breeder facility, is at this time running at full power and is more than one-third through its fourth operating cycle. Reliability and performance of the plant continue to be exceptional. The plant capacity factor, a term used to measure the effectiveness of plant operation, has progressively increased from a very impressive 50 percent for the first cycle to an outstanding 94 percent for the third cycle. The plant capacity factors for this plant are more than competitive with the upper third of the commercial light water reactor plants operating in this country today. And this has been achieved while carrying out a very complex experimental mission. To date, it's logged more than 350 equivalent full power days with an average complement of 55 experiments in the reactor, and has been at full power continuously since January 13, 1984.

A major accomplishment has been the achievement of the goal, more than 80,000 megawatt days per metric ton, burnup of this fuel in a number of the original fuel assemblies, demonstrating the capability of the initial fuel to operate reliably and safely throughout its intended lifetime, which is comparable to that aspired to in most countries.

This achievement was reached in one-third the time required by other reactors worldwide, demonstrating the capability of this facility to advance the state of the art rapidly.

Completed during the third cycle was the first irradiation of the Material Open Test Assembly, MOTA, which has 2,500 structural material samples in over 30 separate temperature controlled canisters. I would add that the complexity and sophistication with the practicality of those experiments is mind-boggling compared to anything in science, including anything in the aerospace field, for example.

These experiments are extending the fuel lifetime to 3 or more years in our fuel.

Assessing the nearly 2 years of FFTF operation, it is clear that the plant has achieved its objective to operate reliably and safely. The inherent safety characteristics of the plant were conclusively demonstrated during the acceptance test program. Designed to assure adequate cooling of the reactor core even with full loss of electrical power, FFTF uses natural circulation of the sodium coolant to maintain sodium flow through the reactor core. In special tests the plant was deliberately scrammed from full power while the coolant pumps were deenergized. Core temperatures remained well within limits throughout the test, confirming predictions and establishing the basis for decay heat removal for larger LMFBR plant designs. This demonstration is a major step toward achievement of the full inherent safety inherency which is key to establishment of public acceptance of the powerplants.

The safety and reliability of the reactor is further emphasized through the record achieved in maintaining personnel radiation exposures at an extremely low level, about 1 percent of that allowed by the very stringent U.S. regulations.

Turning to fuels and materials development, of which I'm most personally intrigued, the driver fuel for FFTF was procured commercially, with fixed price contracts below fair cost estimates. It was produced ahead of schedule, and has met every quality requirement, including operating without a single leak to date, which is unique in this business as far as I know.

The baseline oxide fuel system is in place, in other words, and it works. And to an amazing degree, it's standardized throughout the world. It is supported by an infrastructure of laboratory and production capabilities that are unequaled.

There have been decades of rigorous and comprehensive testing, not just in EBR-II and FFTF, but a complex of test facilities that is a world leader.

The United States has a clear-cut lead in the technology. The small, incremental effort can continue to provide the world leadership which is so vital to safety and safeguards, as well as economic considerations. We are already seeing an increased desire on the part of other nations to cooperate and join with the United States in exchanges and cosponsored tests in reactor and fuel cycle development. I would be surprised, in fact, if we can't get our plutonium, bring it home from other countries, and burn it up, which is a fine way to use it, as a result of this kind of leadership. And in fact, from a personal standpoint, I can't imagine that the rest of the world really will find this ultimate option of the breeder reactor, without which the nuclear eventually runs down, without the U.S. cooperation.

Advanced alloys and materials that will increase lifetimes of both the reactor and fuel assemblies manyfold have been developed in the U.S. principally. An advanced 1,000-day fuel assembly has already achieved over 200 days of operation and fabrication of long-life future cores has been proposed for the near term.

Tests in EBR-II have gone far beyond that of the smaller assemblies.

Turning to automated fuel fabrication, we recognized some years ago that it's absolutely essential for the future, and an integrated system for the automated remote fabrication of breeder fuel is in an advanced development phase. The project is nearing completion and will be installed in FFTF to become operational in 1987.

The secure automated fabrication system could be integrated with a breeder fuel reprocessing capability, where you have unique problems compared to water reactors, but I leave that to Dr. Trauger, who can discuss it far more eloquently and authoritatively.

I would add that for years we have taken the initiative in running a lot of tests which might be described "what if?" For example, what if a sodium pipe breaks and you dump a ton of molten sodium on concrete? We have run repeated experiments where we deliberately dumped red hot sodium and dumped it on concrete, cleaned it up, and ran other experiments. The results were remarkably positive across the board.

What if a fuel pin should fail? That has been a bugaboo for years, decades. We find no catastrophic events when we deliberately run failed fuel: no explosions, no spreading to or melting of other pins. It's so benign we spent our time trying to locate the leak.

Oak Ridge and Argonne's cooperative work in a wide range of reactor safety and high temperature design technology activities has contributed to the overall breeder safety program and has benefited many other high temperature industries.

We've also had technological successes which have spun off both the fusion reactor program and the space reactor program, in which we have also been involved.

Congress has been very supportive in establishing the overall base technology for the oxide fuel cycle.

Surely, too much has been invested, too much has been gained, and the ultimate payoff is far too great to forfeit the major success of the U.S. oxide fuel system which we're on the verge of completing.

Thank you, Madam Chairman.

[The prepared statement of Dr. Evans follows:]

PREPARED STATEMENT OF DR. ERSEL A. EVANS, TECHNICAL DIRECTOR, HANFORD ENGINEERING DEVELOPMENT LABORATORY WESTINGHOUSE HANFORD CO., RICHLAND, WASH.

TEST REACTOR OPERATIONS

The Experimental Test Reactor EBR-II has done a phenomenal job for two decades in testing a wide range of fuels and materials under the most extreme conditions, including operation with deliberately defected fuels.

At Hanford, the Fast Flux Test Facility, the world's most advanced breeder reactor test facility, is at this time running at full power and more than one-third through its fourth operating cycle. Reliability and performance of the plant continue to be exceptional. The cycle capacity factor, a term used to measure the effectiveness of plant operation, has progressively increased from an impressive 50 percent for the first cycle to an outstanding 94 percent for the third cycle. The plant capacity factors for this plant are competitive with the upper third of the commercial light water plants operating in this country today. And this has been achieved while carrying out a very complex experimental mission. During its first two years of operation, it has logged more than 350 equivalent full power days with an average complement of 55 experiments in the reactor. It has now been at full power continuously since January 13, 1984.

A major accomplishment has been the achievement of goal (80,000 megawatt days per metric ton) burnup in a number of the original fuel assemblies demonstrating the capability of the initial fuel to operate reliably and safely throughout its intended lifetime. This achievement was reached in one third the time required by other reactors world wide, demonstrating the capability of this facility to advance the state of the art rapidly. On-plant examination facilities assure that test data is available shortly after irradiation without waiting for long decay times, enabling rapid advancement toward the achievement of fuel systems with truly economical lifetimes.

Completed during Cycle three was the first irradiation of the Materials Open Test Assembly (MOTA). This test has 2500 structural material samples in over 30 separate temperature controlled canisters. These experiments are designed to develop the technology for extending the fuel lifetime to three or more years. This is a key element in the breeder program goal to develop economically competitive breeder power plants. These samples were inspected during the recent refueling. Some were removed for detailed examination, some were returned for further irradiation, and some new samples were added. The reconstituted test assembly is now back in the reactor continuing the test program.

Assessing the two years of FFTF operation it is clear that the plant has achieved its objective to operate reliably and safely. the inherent safety characteristics of the plant were conclusively demonstrated during the acceptance test program. Designed to assure adequate cooling of the reactor core even with full loss of electrical power, FFTF uses natural circulation of the sodium coolant to maintain sodium flow through the reactor core. In special tests the plant was deliberately scrammed from full power while the coolant pumps were de-energized. Core temperatures remained well within limits throughout the test, confirming predictions and establishing the basis for decay heat control for larger LMFBR plant designs. This demonstration is a major step toward achievement of the full inherency which is key to establishment of public acceptance of nuclear power plants.

The safety and reliability of the FFTF is further emphasized through the record achieved by the operational staff in keeping personnel radiation exposures to an extremely low level. The average radiation exposure to the operating staff (i.e. plant operators, maintenance personnel and fuel handlers, the group most likely to receive radiation exposure) is about one percent of that allowed by the stringent U. S. regulations. The maximum exposure to any one individual is less than ten percent of that allowed. This enviable record was attained while achieving excellent plant capacity factors.

Fuel and Materials Development

The fuel for FFTF was procured commercially, with fixed price contracts below fair cost estimates. It was completed ahead of schedule, while meeting stringent quality requirements. Strong participation with and technology transfer to industry was an integral part of development. All fuel and components have performed flawlessly, beyond design limits.

The baseline oxide fuel technology is in place and it works. It is supported worldwide by a wide range of government, industrial and utility laboratory and production capabilities and decades of rigorous and comprehensive testing. The United States has a clear-cut lead in the technology, and with relatively small incremented effort can continue to provide the world leadership which is so vital to safety and safeguards, as well as economic considerations. We are already seeing an increased desire on the part of other nations to cooperate and join with the U.S. in exchanges and co-sponsored tests in reactor and fuel cycle development. For example, Japan has expressed interest in the unique gas tag system of FFTF, which was originally developed with the help of Argonne National Laboratory and the EBR-II. This system detects and identifies the specific fuel assembly involved in the unlikely event a fuel pin should fail during operation.

Advanced alloys and materials that will double or triple fuel/control assembly reactor lifetimes have been developed and are being demonstrated. A test of an advanced 1000-day fuel assembly has already achieved over 200 days of operation and fabrication of an advanced longlife core has been proposed for the near term.

Automated fuel fabrication is absolutely essential for the future. An integrated system for the automated/remote fabrication of breeder fuel is in an advanced development phase. The project will be completed and become operational during 1987.

The secure automated fabrication system (SAF) will be integrated with a breeder fuel reprocessing capability (BRET), currently being worked on at Oak Ridge and Hanford, which could become operational in the Fuels and Materials Engineering Facility (FMEF) at Hanford in 1989. Collocated with FFTF, the FMEF will provide the U.S. with the total capability to demonstrate closing of the Breeder Fuel Cycle. Fuel will be burned in FFTF, sent to BRET for reprocessing; new fuel fabricated in SAF will be returned to FFTF and the safe processing and handling of waste will be demonstrated. The BRET Program is described separately by other testimony, but I would emphasize that for relatively little incremental funding next year, the U.S. is allowed to capitalize upon an enormous amount of accumulated results of work in ORNL and industry, as well as an essentially completed facility (FMEF). These combined capabilities provide an unique opportunity for demonstration of advanced fuel reprocessing technology; establishment of technical bases in the areas of safeguards, equipment reliability and maintainability, environmental and operator impacts, waste management; and effective international cooperation, at the right time and place with the right material (FFTF fuel).

For years, large numbers of tests have been successfully run to answer the "What Ifs?" associated with operational safety concerns. As examples:

- "What if sodium pipes were to break and hot sodium lands on concrete?" To answer this, a special test chamber was built and up to 1000 pounds of sodium ignited and reacted with concrete.

  Results were positive: 1) reactions were relatively limited, and 2) the hydrogen produced was safely burned as it formed due to an accompanying sodium/air reaction.

- "What if a fuel pin should fail?" Test fuel pins were deliberately made to fail and other pins were run beyond design lifetime until they did fail. Results: No catastrophic event, no explosion, no spreading to or melting of other pins. A very benign event, usually a microscopic intergranular crack through the cladding, extremely difficult to even locate.

Oak Ridge and Argonne's cooperative work in a wide range of reactor safety and high temperature design technology activities has contributed to the overall breeder safety program and has benefited many other high temperature industries.

The breeder technological successes have already led to important spinoffs in both the fusion reactor program and the space reactor program.

Congress has been very supportive in establishing the overall base technology for the oxide fuel cycle. However, the most dramatic worthwhile advances in operation and economics lie ahead, and we sincerely request and urge your continued support to achieve them.

Conclusions

Base technology is in place and working. It is backed by long term development and industrial know-how for the oxide fuel system.

Performance of test reactors with fuel and components has been essentially flawless, with inherent safety features demonstrated, but advanced longlife alloys and materials and automated fuel fabrication will significantly reduce core component costs and further improve safety and safeguards. The potential for doubling or tripling core component lifetimes is being demonstrated.

Although we have a highly characterized energy system of proven design and quality, we are only now on the threshold of major technological and economic advances for the overall U.S. program--for a remarkably small incremental cost over the total international investment to date.

In addition to the fuel cycle cost reductions underway, major possible capital cost reductions have been identified.

Closure of the fuel cycle can be demonstrated in the near future by a close, integrated national effort. If the otherwise worthless U.S. stockpile of depleted uranium is utilized in the proposed oxide breeder cycle, it is equivalent in energy to 4-5 times the total mid-East oil reserves.

Congress can provide a breakthrough toward realistic long-range U.S. energy independence by continued support of the base technology programs which are rapidly coming to fruition.

Mrs. **Lloyd**. Thank you very much, Dr. Evans, for a very fine statement.

I believe that your Representative is with us, the Honorable Sid Morrison. He's been very supportive of the programs of this committee. We certainly wish that he were also a member of the committee, but he's very supportive not only in his support, but his support on the floor when we're trying to get important legislation through. So you are very well represented.

At this time I would like to defer to Congressman Morrison.

Mr. **Morrison**. Thank you, Madam Chairman. I really appreciate those kind words, and also the fact that we've had a pretty good team going. Unfortunately, we lost the big one. Now we're looking at what pieces do we pick up on the breeder program.

Dr. Evans, I'm delighted with your statement, and I can also attest for the committee and others in attendance that we're extremely proud of the performance record with the fast flux test facility.

To those who are members of the committee and have been for some years, I want to extend my congratulations because I have seen a significant investment made in America's energy future in the breeder program, and now hope that we can collectively, with the loss of Clinch River, move on to isolate those areas that continue to be the best investment in energy independence for this country. I am pleased that this committee had lent its support to, I think, some positive directions.

As Dr. Evans has indicated in his testimony, we believe to complete the breeder fuel cycle is of greatest importance, to proceed with the fuels and materials testing, which is so effectively under way at the fast flux test facility—and, obviously, the best moves we can take, and we certainly want to cooperate in every way that we possibly can.

Madam Chairman, if I might ask just one question of Dr. Evans while I have the microphone?

Mrs. **Lloyd**. Without objection.

Mr. **Morrison**. Thank you.

Doctor, I notice you emphasized that you had had no trouble at all with the fuel materials that were furnished for the fast flux test facility. These are referred to in a movie which is currently going around the country, Silkwood. I just wanted to have you say one more time that, in spite of the allegations or at least insinuations made in that movie, that there have been absolutely no problems with the fuel elements as constructed by Kerr-McGee for that particular facility.

Dr. **Evans**. Not only is that entirely true without qualification for all those materials which have been questioned, and thousands have been now tested at FFTF, but we have conducted a wide range of both out-of-reactor and in-reactor tests. The Idaho Falls facility, for example, is a transient test facility in which we've operated some pins up to 200 kilowatts per foot of a single 4-inch diameter pin to cause it to fail, and the fuel has performed faultlessly, which is a personally gratifying thing as well as professionally.

Mr. **Morrison**. Is it also true now that there are no other sources available for the construction or the fabrication of breeder fuel assemblies and that that is part of the plan for the FMEF facility?

Dr. **Evans**. That is correct. As of a decade or so ago, we had 10 vendors for the fuel who were willing to bid. We now have absolutely zero. In spite of the immense personal effort and that of my associates to get that fuel produced commercially, we shouldn't be producing it without automation, as we now have pretty well developed in cooperation with industry.

For example, we have a pellet gage that does a phenomenal job of handling, say, 10,000 pellets per hour compared to maybe 10 manually, as done in the past, and doing it much better, and that gage has been through several revolutionary stages, mostly at General Electric now in a large-scale production line. It's not developing toys. It's something that helps the whole industry, and it's unique in the world, something that the world desperately needs and should have. It's an example of what I think leadership really means.

Mr. **Morrison**. Dr. Evans, you're familiar with the BRET program, breeder reprocessing engineering test, which is involved both at Oak Ridge as well as at Hanford. Is this a logical next step as far as the completion of the breeder fuel cycle?

Dr. **Evans**. It is in the world context where every other major country now has or is developing similar facilities, but not facilities such as the FMEF, which is built right. It really is designed and essentially complete now at the right place, on a Government site where it is well protected, right next to a reactor which can provide fuel which is quite different from light water reactor fuel. There's tenfold greater enrichment, for example.

With the kind of cooperation we have had with Oak Ridge, I think we have the right people. They are disappearing rapidly in my organization, from 3,000-something down to about 2,000 people. We're rapidly losing the corporate memory, but it is still there at Oak Ridge in reprocessing. It's the right time and place to do it right and really close that fuel cycle. If we don't, God help the world, because it isn't going to be done right without us.

Mr. **Morrison**. Thank you, Madam Chairman, for your flexibility in allowing me to ask those questions.

Mrs. **Lloyd**. Thank you very much, Mr. Morrison.

I'm sure that Mr. Morrison would agree with me that one of the sources of pride in serving in this Congress, and for me in this committee, is to have constituents who appear before the committee who are very prestigious and knowledgeable and capable leaders in energy research.

I introduced Dr. Weinberg earlier, and it's also my privilege now to recognize Mr. Trauger and Mr. Kasten. I'm also very happy to represent you in the Congress. I certainly welcome you now.

Mr. Trauger, please proceed.

STATEMENT OF DONALD B.TRAUGER, ASSOCIATE DIRECTOR FOR NUCLEAR AND ENGINEERING TECHNOLOGIES, OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENN.

Mr. **Trauger**. Thank you, Chairman Lloyd and members of the subcommittee.

I appreciate the privilege to present testimony concerning the consolidated fuel reprocessing program.

The Oak Ridge National Laboratory has the lead role for the United States in nuclear fuel reprocessing technology development. In this capacity, we have chosen several objectives for future plant design. Foremost are: reduced radiation exposure to workers, minimal environmental impact, improved plant operation and maintenance, improved accountability, no plutonium diversion, and reduced overall capital and operating cost.

These objectives lead to a plant with totally remote operation including sampling and maintenance. Radioactive effluents would be reduced to solids for removal. The process cells would be essentially impenetrable except for airlocks which admit spent fuel and remove product and waste. The program would provide for the eventual reprocessing technology needs for breeder reactors. However, most of this applies equally well to light water reactors and, in a large measure, to reprocessing for all reactor types.

The key to success is in the arrangement of the equipment. Remote manipulators operating from a center aisle provide access to equipment mounted on the walls. New manipulator designs provide the operator with a feel for his actions and, thus, improve both maintenance and operation. Removable racks support components, further facilitating repair or modification. Analytical sampling is by robot. Greatly improved TV viewing completes the concept.

Such systems, when applied to both fuel reprocessing and fuel refabrication, as Dr. Evans has just mentioned, provide diversion control for fissile materials from the irradiated fuel to finished fuel elements. Remote coupling of the information systems offers potential proliferation monitoring for plants which may be placed under the International Atomic Energy Agency's control.

The breeder reprocessing engineering test facility, called BRET, to which Dr. Evans referred, has been designed to perform a key role in demonstrating advanced reprocessing technology. It's been scheduled to be available to reprocess spent fuel from the fast flux test facility. Fortunately, the existing fuels and materials examination facility at Hanford, Wash, will accommodate BRET at a considerable saving in cost.

Conceptual designs and detailed plans exist for the modification of the facility and for the necessary process and control equipment for BRET. The Hanford Engineering Development Laboratory and the Oak Ridge National Laboratory have, indeed, worked in close coordination on this project, and the staff is in place to move forward. We strongly endorse BRET.

Technology development in the program at Oak Ridge National Laboratory also has made good progress, and the integrated equipment test facility is being placed into operation. This facility will test key features of equipment for BRET and will accommodate larger components than are possible or needed in BRET, suitable for a plant, a full-scale plant. The two facilities are complementary and together should provide an adequate base of experience for the design of a fully modern fuel reprocessing plant.

Extension of the breeder program schedule has necessitated reexamination of scheduling for the fuel reprocessing program. This includes international factors. Advanced reactors, largely breeders, have been pursued in many countries. However, fuel reprocessing programs lag well behind the reactors. The consolidated fuel reprocessing program, if carried out as planned including BRET, puts the United States in the forefront of this area. Since international cooperation may become vital for the future, this leadership position could be very important. Some elements of cooperation are already in place with the United Kingdom and Japan.

In summary, I particularly emphasize that the principal features of this program and of the BRET facility are appropriate for all reactor systems, including those for military programs. Incidentally, they also apply in large measure to the handling of other hazardous materials. A considerable investment has been made. The team of experts assembled represents a substantial fraction of the experienced people in the field. Sustained continuation would be cost effective and technologically sound. We recommend that additional funding be provided, so that the important objectives of this program can be achieved on a timely basis.

Thank you.

[The prepared statement of Mr. Trauger follows:]

STATEMENT ON
THE CONSOLIDATED FUEL REPROCESSING PROGRAM

D. B. TRAUGER
ASSOCIATE DIRECTOR
NUCLEAR AND ENGINEERING TECHNOLOGIES
OAK RIDGE NATIONAL LABORATORY

BEFORE THE SUBCOMMITTEE ON
ENERGY RESEARCH & PRODUCTION

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY

February 7, 1984

Madam Chairman and Members of the Subcommittee, thank you for the privilege of presenting testimony concerning the Consolidated Fuel Reprocessing Program. I am Donald B. Trauger, Associate Director for Nuclear and Engineering Technologies of the Oak Ridge National Laboratory.

Our Laboratory has the lead role for the United States in nuclear fuel reprocessing technology development. In this capacity, we have chosen several objectives for future plant design. Foremost are:

Reduced Radiation Exposure to Workers
Minimal Environmental Impact
Improved Plant Operation and Maintenance
Improved Accountability
No Plutonium Diversion
Reduced Overall Capital and Operating Cost

These objectives lead to a plant with totally remote operation including sampling and maintenance. The operator would have no hands-on access to the fissile material which is fully protected. The specification calls for radioactive effluents to be reduced to solids for removal. Thus, the process cells would be essentially impenetrable except for airlocks which admit spent fuel and remove product and waste. The program would provide for the eventual reprocessing technology needs for breeder reactors; however, most of this applies equally to light water reactor fuel and in a large measure to reprocessing for all reactor types.

The key to success is in the arrangement of equipment. Remote manipulators operating from a center aisle provide access to equipment mounted on the walls. New manipulator designs provide the operator with a "feel" for actions, and thus improve both operation and maintenance. Removable racks support components, further facilitating repair or modification . Analytical sampling is by robot. Greatly improved TV viewing completes the concept. Such systems when applied to both fuel reprocessing and fuel refabrication provide diversion control for fissile materials from irradiated fuel to finished fuel elements. Remote coupling of information systems offer potential proliferation monitoring for plants placed under International Atomic Energy Agency control.

The Breeder REPROCESSING ~~Reactor~~ Engineering Test called "BRET" has been designed to perform a key role in demonstrating advanced reprocessing technology. It has been scheduled to be available to reprocess spent fuel from the Fast Flux Test Facility. Fortunately, the existing Fuels and Materials Examination Facility at Hanford, Washington, will accommodate BRET at a considerable saving in cost. Conceptual designs and detailed plans exist for modification of the facility and for the necessary process and control equipment for BRET. The Hanford Engineering Development Laboratory and the Oak Ridge National Laboratory have worked in close coordination on this project and the staff is in place to move forward. We strongly endorse BRET.

Technology development in the program at ORNL also has made good progress and the Integrated Equipment Test facility is being phased into operation. This facility will test key features of equipment for BRET and will accommodate larger plant components than are possible or needed in BRET. The two facilities are complementary and together should provide an adequate base of experience for the design of fully modern fuel reprocessing plants.

Cancellation of the Clinch River Reactor and extension of the Breeder Program schedule has necessitated re-examination of scheduling for the fuel reprocessing program. This includes international factors. Advanced reactors, largely breeders, have been pursued in many countries. However, fuel reprocessing programs lag well behind the reactors. The Consolidated Fuel Reprocessing Program if carried out as planned, including BRET, would put the United States in the forefront of this area. Since international cooperation may be vital for the future, this leadership position could be very important. Some elements of cooperation are already in place with the U.K. and Japan.

I particularly emphasize that the principal features of this program and of the BRET facility are appropriate for all reactor types including those for military programs. Incidentally, they also apply in large measure to the handling of other hazardous materials. A considerable investment has been made. The team of experts assembled represents a substantial fraction of the experienced people in the field. Sustained continuation would be cost effective and technologically sound. We recommend that additional funding be provided so that the important objectives of this program can be achieved.

Mrs. LLOYD. Thank you, Mr. Trauger.

Mr. Kasten, we're certainly happy that you're with us, and would you please proceed with your testimony?

STATEMENT OF PAUL R. KASTEN, DIRECTOR, GAS-COOLED REACTOR PROGRAMS, OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENN.

Mr. KASTEN. Thank you, Madam Chairman.

Madam Chairman, members of the subcommittee, thank you for the privilege for being able to testify before you today.

Oak Ridge National Laboratory is supportive of the congressional initiative to implement a new inherently safe reactor program in fiscal year 1985, and concur that in principle inherently safe reactors are possible. The basic requirement is to provide enough heat capacity and appropriate heat transfer such that fuel-cladding materials do not fail even under extreme accident conditions.

The modular high temperature gas-cooled reactor, which I will call HTR, is a concept which shows promise of achieving the ultrasafe features that are desired. In fact, the ability to achieve and limit the fuel temperatures under loss of cooling conditions from modular HTR's has been demonstrated in the Arbeitsgemeinschaft Versuchsreaktor, or AVR, in the Federal Republic of Germany.

In experiments following full power operation, where the helium circulators were turned off, the main circuit coolant valves were closed, and the control rods were not inserted into the reactor, the AVR fuel temperatures remained well below values at which fuel coating damage and fission product release would occur.

Design features required for an ultrasafe HTR are a low core power density, a negative temperature coefficient of reactivity, and the ability to transfer by passive means a limited amount of decay heat to a heat sink outside the reactor core. All these features are attainable in HTR's.

Further, experimental information obtained to date, while not extensive, indicates that fuel can be fabricated in commercial equipment which will have an excellent fission product retention characteristic, that fuel temperatures can by cycled from 1,100° C. to 1,600° C. and back for a limited number of cycles without significant deterioration in fuel coatings, and that reactor depressurization during normal reactor operations leads to a very low release of fission products.

However, further experimental information is still needed, and not all the significant parameter values have been explored.

In addition to being ultrasafe, HTR's also need to be economically competitive with alternative energy sources. A modular HTR tends to have relatively high costs for the nuclear steam supply system because of the low power density and the relatively low power level. However, most of the capital cost investment lies in the balance of plant, and these costs are normally greatly influenced by the nuclear steam supply system requirements.

With an ultrasafe HTR, however, it should be possible to markedly reduce that influence because of a reduction in safety-related systems resulting in less costly BOP construction.

Further, shop fabrication of the relatively small-sized components used in modular HTR's should increase plant availability and improve economic performance.

Overall, an ultrasafe HTR appears possible to develop, in which licensing concerns are reduced and simplified, and balance of plant costs are reduced. At the same time experimental verification of such performance is needed.

I would like to remark that ultrasafe reactors may be a key way to influence the economics of this system. We know that the present licensing ground rules and the construction practices lead to relatively high costs. An ultrasafe reactor may permit one to change those construction practices and the licensing ground rules.

Key technical areas which need to be investigated for the HTR are: One, the determination of fission product retention by the fuel coatings, graphite and metal surfaces during and subsequent to extreme accident conditions, and, two, the design of a modular HTR plant in sufficient detail to permit an estimate of plant cost based on features which limit fuel temperatures under accident conditions, facilitate shop fabrication, and reduce balance of plant costs.

The key R&D requirements have been identified, and the cost of performing the work has been estimated to be about $70 million over 2 years. Additional R&D, much of which is part of the present HTGR program, is also required to assure that a practical system will be built which will operate satisfactorily over the plant lifetime. The cost of this R&D is estimated at $280 million.

The cost of a demonstration plant of a 250-megawatt demo size is estimated to be $45O million. Further, it should be remembered that developing a modular HTR is pertinent to the development of a very high temperature reactor, or VHTR, which would have future applications for the generation of high temperature process heat.

Building a modular HTR program as an adjunct to the present HTGR program for fiscal year 1985 would result in efficient use of people, facilities, and associated dollars while not losing the momentum of the present program.

We have also made an initial evaluation of the key R&D requirements for the PIUS reactor concept. Carrying out that R&D is estimated to cost about $100 million. We have not estimated the cost of additional R&D or of a demonstration plant.

Inherent safety of the PIUS concept appears excellent. However, a major concern is whether a high plant availability would be achieved. Experimental studies are needed to determine what is attainable in a practical sense.

Thank you.

[The prepared statement of Mr. Kasten follows:]

STATEMENT ON AN INHERENTLY SAFE HIGH-TEMPERATURE GAS-COOLED REACTOR PROGRAM

Paul R. Kasten, Director
Gas-Cooled Reactor Programs
Oak Ridge National Laboratory
Oak Ridge, Tennessee

We are supportive of the proposed program initiative as having potential for providing a new direction for nuclear energy. As we see it, the development of an inherently safe reactor concept such as a modular HTR could result in an ultra-safe reactor plant such that (1) licensing concerns are reduced and simplified, and (2) the relative balance-of-plant (BOP) costs are reduced. Although present HTGR designs have a high degree of safety, meeting the desired modular HTR requirements will require new features and additional research and development to assure high availability and competitive cost.

The key technical areas which need to be investigated for the modular HTR are:

(1) The determination of fission product retention by the fuel coatings, graphite, and metal surfaces during and subsequent to extreme accident conditions;

(2) The design of the modular HTR plant in sufficient detail to permit an estimate of plant costs, based on features which limit fuel temperatures under accident conditions, facilitate shop fabrication, and reduce BOP costs.

(3) The performance of the plant as a function of design, size [e.g., reactor power of 100-500 MW(e)] and the extent and choice of engineered safety features for comparison purposes.

(4) The design and evaluation of pebble-bed fuel handling systems;

(5) The core reactivity coefficients associated with high temperatures and with water ingress, and the development of transport methods to calculate radiation source terms for pebble-bed reactors;

(6) Verification that the thermal transients which could take place in heat exchanger components can be accommodated;

(7) Determination of experimental shielding factors so that designs are developed which lead to low radiation damage of the pressure vessel and other components over the plant lifetime;

(8) Verification that steel pressure vessels will be satisfactory for modular HTR service, and evaluation of steel and prestressed concrete vessels for modular HTR use;

(9) Design of a helium circulator which does not permit water to enter the core region; e.g., a gas/magnetic bearing circulator; and

(10) Selection of a reflector graphite which will last the life of the plant without replacement.

Building a modular HTR program as an adjunct to the present HTGR Program for FY 1985 would result in efficient use of people, facilities, and associated dollars while not losing the momentum of the present program. Transition to a new program could subsequently be planned on the basis of the research and development results and the cost analyses.

Budget requirements (present-day dollars) for the modular HTR development to resolve key technical and economic questions of feasibility are estimated to be about $20M for base technology development, $30M for applied technology development, and $20M for design and economic studies and would cover about a two-year time period. Considerably more effort and funding would be required to develop all the technology needed in building a modular HTR plant. The table of Attachment 1 summarizes the estimated budget needs. The key R&D effort identified above and costing $70M over two years is summarized in more detail in Attachment 2. The additional R&D required prior to completing a demonstration plant and needed to develop a practical plant sums to $280 million and is discussed in Attachment 3. The cost of a demonstration plant is estimated in Attachment 4 to be $450 million.

Since modular HTR development is pertinent to the development of very-high-temperature process heat reactors (VHTRs), and since VHTRs appear important for the future, Attachment 5 briefly discusses R&D aspects of a VHTR program.

In implementing a modular reactor program, we recommend that the following actions be taken: (1) expand the present HTGR Program to include investigating the key R&D areas identified in Attachment 2; (2) determine the acceptability of ultra-safe reactors as a way to reduce licensing and regulatory concerns; (3) obtain specific utility involvement, e.g., ask TVA to (a) furnish the site for an ultra-safe HTR, (b) manage the demonstration reactor project, and (c) buy power generated by the demonstration plant; and (4) ask other utilities to participate in the demonstration project.

We have also made some initial cost estimates of key R&D efforts which are needed in the development of the "PIUS" reactor concept. A summary of that R&D and initial cost estimates are given in Attachment 6.

Attachment 1

Schedule for Technology Development Costs for Resolving Key Questions on Ultra-Safe HTRs, plus Additional Development Costs Prior to Completing a Project

	Budget, $'s M			
	Key Items		Additional	
Item	FY 85	FY 86	Technology	Total
Base Technology (fuels, fission products, materials)	10	10	80	100
Applied Technology (component response, shielding, reactor analysis, component development and testing)	10	20	100	130
Design and Economic Studies (detailed plant design, economic analyses and trade-off studies)	15	5	100	120
TOTAL	35	35	280	350

Demonstration Plant Costs

Estimated cost of a 250 MW(t) [100 MW(e)] demonstration plant: $450M

Attachment 2

KEY RESEARCH AND DEVELOPMENT COSTS ASSOCIATED WITH ULTRA-SAFE HTRs

The key research and development (R&D) areas identified for ultra-safe HTRs are considered in three categories:

(1) Base Technology;

(2) Applied Technology; and

(3) Design and Economic Studies.

Item (1) generally refers to basic information needed to establish the feasibility of the reactor concept; item (2) refers to R&D needed to assure the practicality of components and systems; and (3) refers to the effort required to specify the entire reactor plant in sufficient detail to permit reliable economic estimates of plant performance.

1. Base Technology Development for Resolving Key Issues

The areas which need to be investigated are (1) the effectiveness of fuel and of HTR components in retaining fission products during and following extreme accidents, and (2) the development of reflector graphite which lasts the lifetime of the reactor plant. Nearly all of the effort is associated with the first item which covers detailed experimental data on (a) fuel performance as it relates to fission product retention within the fuel kernels, and (b) the behavior of fission products which would be present in and on graphite, and on component surfaces. Pebble-bed fuel is the HTR fuel of choice in order to obtain on-line refueling, attain high plant availability, and have low fuel cycle costs. Adoption of this fuel would probably lead to use of fuel fabrication technology developed in the Federal Republic of Germany (FRG). It is assumed that a license could be obtained from FRG for fabricating pebble-bed fuel; however, the product fuel would need to be irradiated under reator conditions and subsequently tested under simulated extreme accident conditions to verify that satisfactory retention of fission products is attained. Several fuel capsule tests would be required to demonstrate adequate fuel performance margins, utilizing production-type fuel meeting manufacturing specifications. The capsules need to be instrumented for both temperature measurements and for fission gas release; fuel irradiation temperatures need to cover both "average" and "maximum" values which occur during normal reactor operation, with irradiation to design exposures. In addition, other fuel capsules should undergo the above test conditions, but also be exposed to periodic simulations of a core heatup event with fuel exposure as a parameter. If an improved fuel is required, improved fuel fabrication and QA procedures may be required, followed by a repeat of the above tests using the improved fuel. In all cases, the irradiated fuel would need to be examined extensively in postirradiation examinations to determine the fission product retention performance of the coated fuel particles.

The behavior of fission products which have escaped the fuel coating but are present within the reactor system need to be determined in detail; experimental measurements are needed of the transport of such fission products during and subsequent to severe accidents. Tests would involve heating irradiated fuel pebbles to temperatures of about 1600°C and observing the transport of fission products which occur during various pressure and gas-flow conditions. Also, an in-pile loop test may be needed to study the transport of fission products to component surfaces during simulated reactor conditions, as well as to study the transport of fission products from surfaces to helium coolant under various extreme temperature and flow conditions.

With regard to graphite, the reflector graphite of a pebble-bed reactor should last the lifetime of the reactor plant in order to obtain high plant availability and economic performance. Specialty graphites are available which appear attractive for that purpose, but need to be further developed and tested under simulated reactor conditions, and over the irradiation exposures corresponding to full reactor life, to assure that satisfactory performance is feasible.

The R&D costs associated with the above key areas of base technology are estimated to be $20 million.

2. Applied Technology Development for Resolving Key Issues

The applied technology area covers analytical methods development and their application, plant safety studies, the general technology development associated with components and systems, and the specific testing of components and systems. The items discussed below are the development and application of reactor analysis tools, verification that radiation streaming from the core does not cause significant material damage to components, the experimental response of components when exposed to possible thermal transient conditions, and the testing of pebble-bed fuel handling systems.

Reactor analysis work covers two areas: one is to determine the appropriate nuclear cross sections for low-enriched-uranium/thorium fuel, and to calculate core reactivity coefficients (particularly the reactivity coefficient associated with water ingress accidents). The cross section determinations are also needed for safety analyses, and are useful in estimating fuel cycle costs. The second area covers the development of transport codes to generate an accurate radiation source emanating from a pebble-bed reactor core for use in shielding experiments discussed below.

A number of radiation shielding experiments are needed to determine whether the neutron streaming which takes place from the reactor of a given design is permissible relative to the thermal neutron fluence received by the pressure vessel, cover plates, grid plates, and components such as heat exchangers. These shielding studies will be required for satisfactory design of the core internals and the proper shielding of components. The information obtained will also be useful for estimating equipment maintenance requirements.

The response of components and systems to thermal transient conditions is needed for proper understanding of design requirements. Tests need to be performed under the temperature and flow transients that might exist during extreme accidents, in order to develop components and systems which can withstand such transients without significant damage. The heat convection which takes place as a result of natural circulation flow following an extreme accident is a key cause of thermal transients, and a determination of those transients is needed for specifying component design and placement within the reactor.

The development and testing of fuel handling systems for pebble-bed fuel needs to be performed to establish the practicality of such systems and to give information on reactor reliability using on-line refueling. The fuel transport systems have to demonstrate high reliability, and tests are needed for that purpose.

In order to assure a modular HTR with high reliability, a helium circulator that does not permit water ingress into the reactor system is required. This can be achieved by a gas/magnetic bearing circulator, which is hermetically sealed from the outside environment. Work needs to be performed to determine the practicality of developing such circulators and their associated power supplies, in the sizes suitable for modular reactors.

The estimated cost of performing the above R&D is $30 million, including test facilities for performing experiments.

3. Design and Cost Studies for Resolving Key Issues

A specific plant design needs to be developed for a modular HTR in sufficient detail to obtain a valid cost estimate. This includes the design of components, systems, buildings, and the plant layout; both the nuclear steam supply system (NSSS) and the balance-of-plant (BOP) need to be considered. The influence of design and of plant power level on economic performance are to be studied. The use of annular-type cores having liner cooling on both the inside and outside of the fueled annulus may be a way to increase the power level achievable while still retaining ultra-safe HTR characteristics. Achievement of a higher power level from a unit may lead to improved economic performance.

Because of the importance of economic competitiveness, significant cost evaluations need to be carried out on ultra-safe HTRs. Areas to be investigated include plant construction costs, fuel cycle economics, and plant operation and maintenance costs. Cost tradeoff studies need to be performed concerning design features of the core internals and of plant components and systems (including the NSSS and the BOP); these studies would include evaluation of the use of steel pressure vessels versus prestressed concrete reactor vessels (PCRVs).

The work requires the design of specific components such as heat exchangers, the reactor core and its control systems, fueling mechanisms, pressure vessels, and BOP components and systems. Verification of the practicality of steel pressure vessels needs to be carried out through detailed design and analysis studies which consider both normal and extreme-accident conditions.

The cost of the above studies is estimated to be about $20 million, made up of about $5 million for BOP design, $10 million for NSSS design, and $5 million for economic tradeoff studies.

Attachment 3

RESEARCH AND DEVELOPMENT ON MODULAR HTRs ABOVE THAT REQUIRED FOR RESOLVING KEY TECHNICAL ISSUES

The R&D identified below is a necessary part of developing a practical modular HTR program. At the same time, the work is generally of a nature that there is a high probability that a satisfactory engineering solution will be obtained for the problems being addressed. Much of this additional R&D work is generic with that in the present HTGR Program plan, although specific efforts on components, systems and designs would not be the same. To place R&D costs for modular HTRs into the perspective of the present HTGR Program plan, the following information is provided.

The costs of the present HTGR R&D Program have been estimated to be about $450 million (present-day dollars). The base technology costs are about $90 million; this effort includes work on fuel development, fission product behavior, and materials development (including metals, graphites, ceramics and concretes). The applied technology program costs are estimated at $160 million; this effort includes components and systems technology development, analytical modeling development, use of these models in specifying reactor conditions and analyzing reactor safety, and specific testing of components and systems. The Design and Economic Studies Program is estimated to cost about $200 million, and includes the detailed design of components and systems, and the development of plant designs, taking into consideration base and applied technology information as well as economic factors. Extensive design/licensing activities would require additional funds, but are not considered here since it is assumed that a modular HTR plant would have relatively simple design/licensing interactions which are a part of the normal design process.

For the Modular HTR Program, the base technology R&D costs are estimated to be about $100 million, of which about $50 million would be covered in the present HTGR Program. The applied technology costs are estimated at $130 million for the modular HTR, of which about half is associated with similar component and systems technology development and testing under the present HTGR Program, except for the size of equipment. The R&D costs for design and economic studies are estimated at $120 million for the modular HTR, of which perhaps 30% is closely related to analogous work carried out under the present HTGR Program.

The above sums to a total of R&D effort of $350 million for the Modular HTR Program; of that, $70 million is identified with key R&D studies to be carried out over the next two years and is addressed in Attachment 2. The additional $280 million program is summarized below; a portion of the additional R&D would be obtained under a continuation of the present HTGR Program, as indicated above.

1. Base Technology Development Above That Required for Key Issues

Work in this area covers process development for fuel fabrication, development and testing of fuels, spent-fuel storage studies, behavior of fission products and actinides, and overall materials technology. The overall cost of this program is estimated to be $80 million.

1.1 Process development for fuel fabrication. This work covers both the fabrication of fuel kernels, deposition of coatings on fuel kernels, and the fabrication of pebble-bed fuel elements. The work on fuel kernels and coatings would be essentially the same as under the present HTGR Program; however, the process development for fuel element fabrication would be significantly different since pebble-bed fuel would be fabricated rather than prismatic fuel elements. The process for fabricating pebble-bed fuel would probably be obtained from the Federal Republic of Germany (FRG) through a license arrangement; however, additional work on processing development would be needed to obtain an understanding of the importance of specific processing parameter values on fuel performance. The estimated cost of the overall fuel process development is $20 million, which is slightly higher than the cost of the corresponding work on prismatic fuels in the present HTGR Program.

1.2. Development and testing of fuels. This work pertains primarily to irradiation testing and examination of fuels produced in commercial-scale production equipment. The emphasis would be on determining (a) fuel performance under normal operating conditions, (b) fuel performance under certain "upset" conditions [e.g., influence on performance of increased water vapor concentation in the coolant], (c) the impact of on-line refueling on the integrity of pebble-bed fuel, and (d) the proper handling and storage of fuel after removal from the reactor. This effort is estimated to cost $10 million.

1.3 Fission product and actinide behavior. R&D in this area would place emphasis on nuclide behavior under normal reactor conditions. This includes study of (a) the behavior of plutonium in the graphite matrix of the pebble fuel [such plutonium occurs because of neutron capture in uranium present in the graphite matrix material], (b) the amount and nature of fission products present in graphite "dust" within the reactor circuit, (c) the transport mechanisms associated with movement of fission products and actinides, and their importance on the activity levels of components, and (d) the influence of changed operating conditions [e.g., lower or higher reactor power level] on fission product transport properties. The cost of carying out the above effort is estimated to be $10 million.

1.4 Materials technology development. The Materials Program would investigate metals, ceramics, graphites and concretes. The metals and ceramics studies would differ little from those in the present HTGR Program plan. Information needed is the detailed materials properties used in designing and operating components and systems and includes material behavior under conditions of creep, fatigue, corrosion, and reactor radiation. Other testing areas concern fracture mechanics, mechanical, and weldment properties. An extensive materials data base is needed to design heat exchangers, thermal-barrier cover plates, the core support structure, the pressure vessel, circulators, and reactor internals.

The Concrete Materials Program is dependent upon the choice of reactor pressure vessel. Steel vessels are under consideration for modular HTRs at this time, although prestressed concrete reactor vessels (PCRV) also may be attractive. Further, if an annular HTR were developed which would have less limitatin on power level while still retaining ultra-safe HTR characteristics, the PCRV would be the pressure vessel of choice. As a result, the R&D program summarized here retains the concrete development work of the present HTGR Program, and also includes the R&D needed for a steel pressure vessel. For the latter, there is need to qualify the steel-vessel materials for modular HTR service, including conditions occuring during extreme loss-of-cooling accidents. For the PCRV, there is a need to develop high-strength concretes based on use of materials from candidate sites. Properties of such concretes (e.g., strength, modulus, thermal behavior, and time-dependent behavior) would need to be obtained.

Under Graphite Development, work would be needed on developing core support graphites as given in the present HTGR Program. In addition, R&D would be required in qualifying a feasible graphite for use in reflector service. This effort involves the performance testing of graphite fabricated in commercial facilities, and the accumulation of an extensive data base which permits adequate reflector design for reactor lifetime service. The work includes fracture mechanics studies, physical property measurements of strength and creep behavior, and irradiation testing.

The overall cost of the above Materials R&D Program is estimated to be $40 million.

2. Applied Technology Development above that Required for Key Issues

Work in this area considers: (a) the development and verification of analytical tools and their application in reactor design and evaluation,

(b) safety and risk analyses, (c) the development of general technology associated with components and systems, (d) the specific testing of prototypical components and systems important to demonstrating a practical plant, and (e) reactor and plant control systems, coolant flow control systems, service systems, and heat exchanger systems. The overall cost of this R&D is estimated to be $100 million.

2.1 **Analytical model development and application of these models.** This effort would be closely related to that in the present HTGR Program. The work includes the development, update, verification, documentation, review, and maintenance of computer programs used in HTGR designs and economic analyses. The associated analytical models are used in core design, system design, component design, and economic evaluations; the models include calculational methods used in shielding, structural mechanics, and seismic analyses. This effort also includes verification of the validity of the calculational models, based on experimental information obtained in other parts of the R&D program. The cost of this work is estimated to be $15 million.

2.2 **Safety and risk analysis.** The effort in this area includes specific evaluation of the safety of the modular HTR under extreme accident conditions, using analytical models developed in Section 2.1 above. It also includes probabilistic risk analysis for a wide range of conditions; risks evaluated will include those for the public and the plant operators, as well as the commercial risks associated with the plant itself. Factors to be included under commercial risk analysis include the times required for building cleanup under circumstances of fission product release from the core circuit to the reactor building. The cost of this activity is estimated to be $5 million.

2.3 **General technology development for components and systems.** The R&D effort in this area provides information on the structural, mechanical, heat transfer, and fluid flow relationships which apply under the conditions expected in components and systems of the reactor circuit. Experimental testing would generally involve only part of a component or system, or be a scaled-down version of the prototype to be tested later. The information obtained would help determine the final designs of prototype equipment. Work would include study of coolant flow conditions below and above the reactor core, development of control technology for both the reactor core and the reactor plant, testing of ceramic pads under various conditions of thermal gradients and mechanical loads, development of equipment for servicing the reactor, evaluation of pebble flow through the reactor, structural and mechanical testing of the reactor internals, heat transfer conditions in the pebble bed core and in the steam generator, and thermal barrier development. The cost of the above effort is estimated to be $20 million.

2.4 Testing of prototypical components and systems. Work carried out in this area includes testing of the fuel handling system, circulator and associated system, pressure vessel heat disposal system, steam generator, core support structure, thermal barriers, control systems, and reactor service equipment. On the basis that an annular HTR will be considered, a test of a model PCRV (prestressed concrete reactor vessel) would be performed; tests of the "closures" which seal PCRV cavities would also be conducted. On the same basis, a test of the "hot duct" between the core annulus and PCRV cavities (for placement of steam generators) would be performed. The fuel handling system for transport of pebble-bed fuel must be tested for endurance. The heat disposal system would require testing for reliability, since it will remove reactor heat following an extreme accident; these tests would be different with use of a steel pressure vessel than with a PCRV since the liner cooling system is within a PCRV, and would be outside of a steel vessel. A major test is that of the circulator, which desirably would have gas/magnetic bearings to improve reactor reliability and to remove the circulator as a source of water or oil to the core region. The core support structure arrangement may be dependent upon the choice between a PCRV or a steel pressure vessel. It is assumed at this time that a structure similar to that in the present HTGR will be retained, with test requirements similar to those in the present HTGR program. The steam generator test would include experimental studies of natural convection heat transport between the core and the steam generator under conditions of no forced convection, with system pressure as a parameter. Testing of prototypical control rods and their drive assemblies would also be carried out, as would testing of the practicality of full-scale reactor service equipment.

Overall, it is estimated that the above R&D program would cost $60 million, including the cost of needed new facilities.

3. Design and Economic Studies Above That Required for Key Issues

This effort is to develop the detailed design of a nuclear steam supply system (NSSS), the preliminary design of the balance-of-plant (BOP), and the economic performance and tradeoff studies required to determine the design of a practical power plant. The study areas are identified as: (a) overall plant design, (b) design of reactor primary components and systems, (c) design of reactor services and operations, and (d) BOP design. The overall cost of performing this work is estimated to be $100 million for a 250-MW(t) demonstration plant; this estimates considers that the interactions of design activities with licensing requirements are significantly reduced because of the ultra-safe features of the plant.

3.1 Overall plant design. This work includes (a) maintaining all of the plant design interfaces which are necessary to develop an integrated and efficient plant design, (b) licensing activities as they relate to developing an acceptable plant design, and (c) performing overall studies of plant safety and investment risk as they relate to developing an economic plant design. The activities would consider items such as plant performance, plant seismic requirements, plant availability, plant startup and operation, economic tradeoff studies, safety criteria and requirements, investment risk analysis, safety analysis reports, environmental reports, and topical reports covering specific technical areas which need review. The estimated cost of performing the above work is $20 million.

3.2 Design of reactor primary components and systems. This activity covers the design of components and systems such as the (a) reactor pressure vessel, (b) reactor and coolant flow control system, including safety-related control and instrumentation, (c) reactor internals, (d) reactor core, and (e) the primary coolant system. The pressure vessel design would consider that either a steel vessel or a prestressed concrete reactor vessel (PCRV) could be utilized. Design of the steel vessel would have to consider the acceptability of thermal transients which could take place, as well as the acceptability of the neutron damage which occurs. The PCRV design would include consideration of the liners, penetrations, closures, thermal barrier, and cooling water systems which are integrated with the PCRV.

The design of reactor control systems includes consideration of equipment, instruments, controls, and system integration. Specific items are control rods, reserve shutdown rods/systems, in-core sensors, flow measuring devices, safety logic devices and associated instrumentation such as moisture monitors.

Design of the reactor internals includes the design of the core support floor, the permanent side reflector, core peripheral seal, core lateral restraint and side shield, and the plenum structures. Reactor core design involves reactor physics analysis, core thermal and hydraulic performance, analysis of stresses in the core and reflector, and shielding design.

The design of the primary coolant system considers items such as the circulators and their service system, the steam generators, and the transport and distribution of fission products within the coolant system as a function of design parameters.

The cost for performing the above work is estimated to be $45 million.

3.3 Design of reactor services and operations. The effort for this activity includes the design of components and systems such as the (a) fuel handling equipment and systems, (b) reactor servicing equipment, (c) helium purification system, (d) plant control system, and (e) the plant data acquisition and processing equipment. The fuel handling task performs the design of the overall fuel handling system (including the equipment, system control, and the interfacing with fuel storage systems).

The design of reactor servicing equipment considers systems which facilitate reactor inspections, servicing, maintenance, and component replacement.

The design of the helium purification system provides equipment and systems for removing impurities from the helium coolant; the process involves forcing a "purge" stream of helium from the reactor through equipment which removes impurities (such as hydrogen or dust particles) prior to return of the purified helium to the reactor.

The design of the plant control system determines the instrumentation used to control items such as steam temperature and pressure, circulator speed, reactor power, and feedwater flow; it also determines the circuitry required for equipment protection.

Design of the plant data acquisition and processing equipment establishes the detailed requirements of instruments, computers, and systems for measuring process variables, so as to operate the plant in a safe, efficient, and economic manner.

The overall cost of performing the above work is estimated to be $15 million.

3.4 Balance-of-plant design. The BOP costs are dominant items in the capital costs of todays nuclear power plants; however, the BOP costs are strongly influenced by the NSSS requirements. The effort here is to develop the BOP design on the basis that the NSSS of an ultra-safe HTR has limited influence on the BOP design, and determine what is possible in reducing plant capital costs. The specific influence of NSSS requirements on BOP design also needs to be addressed by strong interfacing between the NSSS and BOP design efforts. In this process, a number of economic tradeoff studies will be required, which involve components and systems of the NSSS and the BOP; the results of these tradeoff studies will help specify the detailed design of a practical HTR plant.

The estimated cost of this activity is $20 million.

Attachment 4

ESTIMATED COST OF A DEMONSTRATION MODULAR HTR

Cost estimates for a demonstration modular HTR plant are very uncertain since the detailed design of such a plant has not been completed. Results given here are only indicative of the general magnitude of demonstration plant costs.

In estimating demonstration plant costs, information used was that available on the costs of the Arbeitsgemeinschaft Versuchsreaktor (AVR) pebble-bed reactor in the Federal Republic of Germany (FRG), the costs of the Peach Bottom HTGR, estimates of modular HTR costs made within the present HTGR Program, and by the Nuclear Research Center in Juelich, FRG. The cost information on the AVR and on the Peach Bottom HTGR is noteworthy inasmuch as these plants were actually built and operated; also, they were licensed under conditions which might be representative of the conditions which would be imposed on an ultra-safe HTR.

Table 1 lists the summary construction costs for the AVR and the Peach Bottom (PB) HTGR; column 2 gives the MW(t) of the reactor, while column 3 lists the MW(e). Column 5 gives the estimated cost if built at the date given in column 4, while column 6 gives the estimated cost in 1984 dollars. Column 7 gives the direct construction costs of a 250-MW(t) unit [100-MW(e)] estimated by considering costs to vary with power level to the 0.7 power.

Table 1 also gives corresponding information on the AVR-250 [a 250-MW(t) version of the AVR, and obtained from FRG], and on the HTGR-300 [a 300-MW(t) modular HTGR developed by participants of the present HTGR Program]. The costs for the above two units were for "nth-of-a-kind" plants. However, as seen from column 7 in Table 1, the extrapolated direct construction costs for 250-MW(t) units of "AVR-250" and the "HTGR-300" are not much different than the extrapolated costs for the AVR and the PB-HTGR. This may reflect the different licensing and project management conditions which existed at the times the AVR and PB-HTGR were constructed; if so, the "nth-of-a-kind" unit costs for the AVR-250 and the HTGR-300 may correspond to "demonstration plant" unit costs. On that basis, the direct construction costs for a 250-MW(t) modular HTR demonstration plant are estimated to be $180 million; indirect costs covering construction services, field engineering, architectural engineering services and fees are estimated to be $170 million. The sum of the above is $350 million; adding a 30% contingency gives a total estimated capital cost of $450 million for a 250-MW(t) demonstration plant. The above is exclusive of the cost of the first core loading.

Table 1. Direct Construction Cost Summary for Selected HTRs

Reactor	MW(t)	MW(e)	Date of Cost Est.	Direct Construction Costs, $M Cost in then Current $s	Direct Construction Costs, $M Cost in 1984 $s	Direct Construction Costs of 250-MW(t) Unit, $M (1984 $s)
AVR	46	15	3/81	49	59	193
PB-HTGR	115	45	5/67	26	87	150
AVR-250	250	100	3/81	169	204	204
HTGR-300	300	114	1/82	183	206	180

Attachment 5

RESEARCH AND DEVELOPMENT PROGRAM FOR MODULAR VERY-HIGH-TEMPERATURE REACTORS (VHTRs)

Modular VHTRs appear particularly appropriate for the generation of high-temperature process heat; such systems would permit nuclear energy to make important new contributions toward meeting the energy generation requirements of the future. The development of VHTRs builds on the above modular HTR program, but a key new need is the development of materials for service temperatures up to 900-1000°C. This requires long-term development; early R&D emphasis should be placed on the development of practical high-temperature materials, on design and cost studies for guidance, and on maintaining and expanding international cooperative programs involving technical development. A level of support of $5 million per year for the next few years would permit a meaningful program, with about $3 million of that allocated to materials development, $1 million for design and cost studies, and $1 million for international program activities.

1. VHTR Base Technology Program

The emphasis would be on development of high-temperature materials. The overall VHTR materials program would be more expensive and of longer duration than that for the steam-cycle modular HTR. On the basis that the steam-cycle HTR R&D program would be carried out, a VHTR materials program is estimated to cost an additional $70 million and require 15 years. Elements of the VHTR materials program are as follows.

Alloy Design and Development. This work involves the development of high-temperature materials for VHTR components, and includes the qualification of materials for their intended use. It appears necessary to develop and test new alloys. The estimated cost of this program is $30 million over 12 years.

Development and Design Data. An extensive compilation of material properties needs to be obtained for proper design of components and systems. Components of interest include heat exchangers, thermal barrier cover plates, core support structures, and the pressure vessel. Design criteria need to be established based on material properties; metallurgical features such as weldments need to be related to specific component configurations; qualification studies are needed which require fracture mechanics, mechanical and physical properties, corrosion, and weldment data. The cost of this program is estimated to be about $40 million over 15 years.

Additional base technology development would be required for (a) qualifying fuels for VHTR operating conditions, (b) obtaining the associated behavior of fission products and actinides in VHTR systems, and (c) qualifying graphites for high-temperature use. The cost of these efforts is estimated to be $30 million over 10 years.

The above gives a total base technology R&D effort for VHTR development of $100 million, which is in addition to the R&D expenditures for the modular steam-cycle HTR.

2. VHTR Applied Technology Development Program

Work in this area covers analytical modeling development, application of the resulting models toward specifying reactor design and operating conditions, safety studies, component technology development, and testing of components and systems. Components to be included are intermediate heat exchangers and reformers. A rough estimate of applied technology development costs above those for the modular steam-cycle HTR is $100 million over 10 years.

3. VHTR Design and Cost Studies

The work carried out here covers the design of the nuclear heat supply system (NSSS), the design of the balance-of-plant (BOP) as it is influenced by the reactor plant, economic tradeoff studies, and application studies. The effort is to develop the conceptual design of a demonstration plant, and help guide the applied technology program. Costs for this activity are estimated to be $50 million over 10 years. Additional support would be required to develop the detailed VHTR design; that effort is dependent upon the results obtained from the above R&D program.

4. VHTR Demonstration Plant Costs

It is too early to estimate the cost for building a VHTR demonstration plant. The costs are highly dependent upon the materials developed under the high-temperature materials development program and the cost of components made from such materials. Under fortuitous conditions it might be possible to modify a modular steam-cycle HTR demonstration plant to accommodate a VHTR, but the cost of that modification is highly uncertain and dependent upon many factors which are presently unknown. A modular VHTR demonstration plant would tend to have a higher cost than a demonstration modular steam-cycle HTR plant.

Attachment 6

KEY RESEARCH AND DEVELOPMENT REQUIRED ON THE PIUS REACTOR CONCEPT

The PIUS reactor concept has been proposed as a very safe reactor concept built on LWR Technology. Further, it might be a system which has a low capital cost because of its safety and control characteristics. The practicality of the concept rests on the stability and control of the fluid interfaces between the pool water and the hot primary circuit, including stability under transient conditions. Other important factors are the practicality of the PCRV design, of refueling, of insulation requirements, of replacement of equipment, the practicality of operating the reactor without any control rods, and the practicality of developing steam generators and pumps with very long lives.

The objectives of the R&D program are to evaluate the practicality of the PIUS reactor concept. Seven technology areas to be covered are: (1) the practicality of the concept relative to maintaining separation of the boronated water from the primary coolant under normal operating conditions, including changes in power level; (2) evaluating the practicality of operating a PIUS type system with no control rods per se; (3) evaluating the technology and economics of PCRVs as proposed in the PIUS concept, including evaluation of closures; (4) evaluating the downtime required to refuel the reactor and to replace equipment, and the effects of the estimated values on plant availability; (5) determining the insulation requirements of the reactor vessel and of the PCRV, and whether there are significant costs in the use of insulation; (6) evaluating the overall economics of the PIUS reactor concept; and (7) developing practical heat exchangers and pumps.

The seven areas listed above are treated separately below.

(1) It is important to demonstrate experimentally that under normal reactor operating conditions the boronated pool water region is maintained separately from the primary coolant, and that under loss of primary coolant flow natural convection forces will cause boronated pool water to circulate sufficiently through the core region. The various factors affecting the position of the hot fluid-cold fluid interfaces would be investigated in detail. It would be necessary to construct engineering test facilities and carry out tests to demonstrate the practicality of the PIUS control system. This would involve building a large test facility, including vessels, heat exchangers, pumps, heaters, piping and associated instrumentation and control. The size of the facility would, in general, correspond to a 1/10th-scale in diameter and full-scale in height, since the natural circulation circuit needs to be prototypic. Several different experimental arrangements may be

needed. A 1/10th-scale diameter size would correspond to about a 16-MW(t) unit; however, a power level of about 5-10 MW would probably be sufficient.

(2) Use of ion exchangers to control boron concentration in the core region, and the ability to eliminate control rods would be evaluated through detailed analysis. This effort would include study of the rate at which boron concentration changes can be made, the practicality of having no control rods per se, and the implications of having no control rods on reactor plant costs.

(3) The PCRV vessel which is proposed is a very large structure, and it is proposed that such a vessel be surrounded by earth. The practicality of such a design, the ability to maintain and check its integrity, and the associated costs would be evaluated. Further, the closures and closure seals would be studied from the viewpoint of their practicality, operability, and their ability to facilitate fuel loading and unloading and equipment replacement.

(4) Refueling the reactor involves placement of spent fuel into storage racks inside the PCRV, and placement of fresh fuel elements into the core. The practicality of long-time storage of spent fuel elements inside the PCRV needs evaluation, as does the practicality of eventually removing spent fuel elements through the special closure opening of the PCRV, and of refueling the core. Also, in the case of equipment breakage, it might be necessary to replace pumps and heat exchangers, and the practicality of such replacement needs to be evaluated. A demonstration of the proposed refueling procedure as well as experimental studies of the replacement of components is required, demonstrating the practicality of techniques planned for use.

(5) The insulation requirements need to be evaluated using detailed analysis. The practicality of these requirements needs to be determined.

(6) The overall cost of a PIUS system would be evaluated relative to a conventional PWR. This would take into consideration the results of the technology evaluations of the PCRV and of the control systems, and the influence of constructing a PCRV on site on overall plant construction schedule and costs. This would also require significant design studies to be useful, and these would only be performed after the other studies were completed and only if the results obtained were favorable. Licensability studies, e.g., a mini safety analysis report, should be included in the above.

(7) The development of heat exchangers and pumps which have high performance over long times is essential to maintaining reactor availability at practical levels. A new type of heat exchanger is preferred which will require development and testing in prototype sizes. The pumps are to be similar to those already utilized in Sweden, but prototype units still need long-term testing. Low maintenance of these components is required to avoid long periods of reacto downtime associated with their replacement.

Cost and Schedule

The items discussed above are treated separately below.

(1) The estimated construction cost of the facility for experimental studies is estimated to be approximately $30 million; in addition, abou $10 million of research and development funding is needed over a three-year period for reactor operations testing, analyses, performance evaluation, and demonstration. A less costly simulation may give useful information but would not be prototypical. About $5 million would be needed in FY 1985 to perform detailed design and planning, and order/obtain equipment associated with the power supply and heaters.

(2) Preliminary evaluation of the control and control-rod systems is estimated to cost about $100,000; however, experimental development of control systems may be required as a result of the initial evaluation, and this effort sould require an expenditure of about a million dollars over a period of about two to three years. $100K would be required in FY 1985 for analyses and evaluation.

(3) The preliminary evaluation of PCRV performance would require about $300K, along with detailed design informatin on the PCRV vessel and on closure construction from ASEA-ATOM. PCRV model testing may also be required, and such model testing would cost about $3 million over a three-year period. Closure testing will be required and cost approximately $2 million. About $300K would be required in FY 1985 for evaluation studies.

(4) Refueling studies would require demonstration of the proposed refueling procedure, based on prototypic equipment. Experimental studies on the replacement of components would also be performed. The response of the "chimney" separating the primary circuit from the outer pool to seismic events may also be needed. These demonstrations are estimated to cost about $5 million, and require two to three years to complete. $100K would be needed in FY 1985 to initiate planning and evaluation methods.

(5) The practicality of proposed insulation systems (e.g., heat loss, durability) would be experimentally studied under simulated reactor conditions. Overall cost is estimated at $1 million. About $100K would be required in FY 1985 to initiate this program.

(6) The overall economic evaluation of the concept would be dependent upon the details available for the cost estimate. Based on preliminary information and preliminary conceptual design information, a preliminary overall cost estimate could be performed for about $500K. However, a detailed design is needed to obtain a reliable cost estimate, and such a design effort would require at leat $10 million over several years, including licensability studies. This latter effort is proposed only after satisfactory results are obtained from the previous work areas. $100 would be required in FY 1985 to initiate the preliminary economic evaluation.

(7) Design of the steam generator, construction of a prototype, and testing the unit under the various operating conditions to be expected needs to be carried out over long time periods; testing of the prototype pump under simulated reactor conditions and long times is also needed. The cost of performing this work (and constructing the facility required for the testing) is estimated to be about $40 million. About $1 M should be spent in FY 1985 to perform preliminary design work and plan the specific test to be performed.

Mrs. LLOYD. Thank you very much, Mr. Kasten, for your very fine testimony.

Dr. Evans, as you know, the administration has substantially reduced the fuel cycle R&D program for fiscal year 1985 and has also proposed termination of the BRET program initiative. Of course, you also know that this initiative was recommended and it was approved by this subcommittee last year, and I think you will agree that it is essential to producing a safe, reliable, as well as a cost-effective fuel recovery capability for our future breeder reactors.

Under these constraints, what sort of things need to be done at Hanford to support the BRET effort?

Dr. EVANS. Well, first, we're not the only ones being hurt in the fuel cycle. The work at Oak Ridge is equally or more indispensable.

The principal thing we lose, I believe, is to begin installation, which could be done fairly shortly in the case of the automated fabrication equipment in the FMEF, which is essentially complete this year.

If BRET is zeroed out, I think it will be devastating. I don't know how we could warm it up again.

Mrs. LLOYD. Mr. Trauger, do you think that we need BRET now? Do you think we could wait until a later date when we feel that the breeder will be needed or what is your reaction to this? Would you define a little bit more the ORNL role in the BRET program?

Mr. TRAUGER. Yes. We think that BRET is a very logical next step. It provides a focus for the program, and it provides a tangible demonstration of these important features for fuel reprocessing plants, which I mentioned early in my testimony.

The existence of the FMEF and the existence of the people that are working—have worked on BRET—to carry on into the BRET operation is an important factor.

If the program is cut back as severely as the President's budget would suggest, we will lose a great many people from the program in Oak Ridge and we will lose both highly experienced people who are now becoming less and less available as retirements take place, but also young people that we have been training to follow on and who would be available to provide new capabilities for future plants down the road, whenever they may become available. So maintaining the continuity is very important in both our program and BRET, in which we are an important part.

We are assisting very heavily, in answer to your question, in the choice and design of the components which go into the BRET facility and in preliminary testing of equipment and preliminary design of those pieces of equipment and of the facility itself. It's a very closely coordinated operation between Hanford and Oak Ridge. It's been an excellent example of cooperation.

Mrs. **Lloyd**. Of course, DOD has expanded their reprocessing capabilities at the Purex plant in Washington. Do you feel that the BRET program, as well as other programs that are funded with advanced fuel cycle R&D programs in prior years, provides the capabilities that aren't presently with DOD's reprocessing program?

Mr. **Trauger**. I believe that our designs and the features of our program and of BRET are at the present time unique, not only in the United States, but in the world, as far as new technology and improved operability and improved features from the standpoint of safeguards and protection of workers. And it's for that reason that I'm very enthusiastic about this program.

Mrs. **Lloyd**. Dr. Evans?

Dr. **Evans**. I'd like to add that I think Oak Ridge, Dr. Trauger and Dr. Burch and others have kept a remarkable rapport with other countries around the world in reprocessing. I have visited other countries many times, but a couple months ago in France I was struck by the awesome—it's nothing but an awesome commitment of France to reprocessing.

Mrs. **Lloyd**. You're answering the next question I was going to ask you: France's fuel cycle technology in comparison to ours.

Dr. **Evans**. It overwhelms anything I've seen in the United States in the reprocessing area because they've made that commitment. It's the biggest project in Europe, as your staff undoubtedly knows.

One small part of it, really, is a facility that's highly automated, completely automated, for doing the kind of work we're talking about. It's only a part of it.

We're going to lose that kind of exchange. We talk about international cooperation. I think it's a figment of our imagination unless we have some leadership. We have it. It complements what France does. We aren't really losers; we aren't all that shabby. France quickly admits that at every level in their nuclear effort.

They have large reactors, including breeders. We have relatively small ones. But when it comes to the fuel cycle, we have every reason to believe we're already radiating fuel which will have a twofold or threefold increase in lifetime. The French don't have it. They don't have a test facility where they could ever test it. They're not going to put such material into production reactors.

So if we're going to have a long-life fuel which cuts fabrication costs severalfold, cuts the reprocessing to be done severalfold, it's going to be done right here at home. The BRET and the SAF line are the way to do it. We have no other alternative. As I indicated, it is absolutely zero in industry, because we have rapidly cut back, considering the scale of what we're trying to do.

Mrs. **Lloyd**. Mr. Trauger, would you care to comment further on this?

Mr. **Trauger**. I would just observe that we have had a number of expressions from the French with interest in our program, which suggests that we do have something that they would find of interest. We think there is good opportunity for international cooperation in a number of areas, which could save costs for us and for others as well.

Mrs. **Lloyd**. Thank you very much.

Mr. Kasten, we're going to turn to another issue with you.

As has been stated several times in this hearing, the quality of our nuclear plants really has not been perceived to be very high. In some instances it really has not been perceived to be really adequate. I think that Time magazine bears out this perception. I think that the safety of the plants is being questioned by the public, and this is one of the perceptions that we hope to overcome. For this reason, I'd like you to explain power density to us and what this has to do with the inherent safety features which that we are wanting to move toward.

Mr. **Kasten**. Power density, of course, is a measure of the unit amount of power, per-unit volume of core volume, like kilowatts per liter or kilowatts per cubic foot, in the core system. The higher the power density, the higher the rate of temperature increase of the fuel following loss of cooling. So if you have a low power density and you have a loss of cooling accident, the response of the system would be that the temperature would rise at a much slower rate with a low power density system than with a high power density system. This gives more time in which to transfer energy to other systems without causing damage to the fuel.

If you also have a system which has high temperature capability as well as high heat capacity per unit volume, then you have an additional length of time, and that's why the high temperature gas-cooled reactor has inherent features are very satisfying from the viewpoint of being able to build a practical system.

Mrs. **Lloyd**. Well, thank you very much. I do wish we had more time, but thank you for your very fine participation this morning. We will certainly be hearing from this committee more.

I would like to ask, without objection, that all of our panelists would agree to further—pardon me, Mr. Chandler—that all of you would agree to questions in writing from this committee.

Mr. Chandler, forgive me for overlooking you.

Mr. **Chandler**. How could you overlook a 6-feet 4-inch guy from the State of Washington? [Laughter.]

Mrs. **Lloyd**. Well, let's put it this way: I wasn't looking in the right direction.

Mr. **Chandler**. That's right.

Well, thank you very much, Madam Chairman.

My compliments, also, to the very distinguished panel.

Just a couple of questions for you, Dr. Evans. First, this morning we've heard discussion of inherent safety, and in your testimony on page 2 you said that the FFTF was designed to assure adequate cooling of the reactor core. Was that a goal that was in mind? Was that something you set out to do? Was that an option that you didn't have to pursue? Could you comment a little bit on that, because I think it's important to the discussion that we've had earlier?

Dr. EVANS. Yes, it was designed, and a great deal of time was spent on that design with worldwide reviews of the possible aspect of it at the time.

It is designed in case a pipe broke or something with the coolant around the core. Because of the tremendous thermal conductivity, you'd keep the core as cool as possible.

But then at that time we didn't know until we actually tested it that the natural circulation would work, which means in this low pressure coolant, essentially atmospheric pressure close to it, you can literally turn off the pump. It's mind-boggling to think of poking a button and suddenly the pumps aren't running, and yet the reactor cools itself down very predictably, and it's not just a "go or no-go" thing. That we learned after we built the reactor.

But a very substantial part of our total effort at Hanford, but also at Argonne and test facilities such as TREAT, and throughout the country with the help of industry in practically all of it, we have conducted similar tests to satisfy these concerns. It's been understated, if anything.

Mr. CHANDLER. I'd also like to ask you about the relevance of the work at Hanford in terms of the fuels. Is the fuels work reaching fruition in water- and metal-cooled reactors applicable to smaller or alternative reactors, again relating back to the discussion that we heard earlier this morning?

Dr. EVANS. I think essentially all of this fuel work, to a remarkable degree—I would say 90 percent of it—the data has been accumulated, the computer codes are a 50-foot high stack of metal handbooks and so forth, to provide the information needed for whatever reactor we want to build for aerospace or other applications. I don't think we need to start all over reinventing everything. It is documented, highly accurate data that has been generated and massaged by all our peers worldwide, most of it, what we've released.

So I've been involved in aerospace reactor work for many years, heavy water reactors, gas-cooled, metal. I find a common denominator worldwide. There have literally been billions of oxide fuel pellets fabricated around the world, and they operate, and we sort of take that standardization for granted. It's a big part of the total safety and economic picture for the entire world's reactor business.

Part of it is, can you build a reactor in a timely, economic, safe way? The other is, when you get it built, can you afford to run it? I'm saying the United States has a dominating lead demonstrated with the capabilities we still have in place—barely—to continue that lead, and that's where we're going to get our exchange if we're going to have an international exchange. Otherwise, that's just a lot of hot air.

Mr. CHANDLER. Thank you very much, Madam Chairman.

Mrs. LLOYD. Thank you very much.

And, again, thank you for appearing before us today.

Our next panel, we have Mr. George Dilworth, who is assistant manager of the Tennessee Valley Authority, as well as Mr. Jim Dager, who is vice president of engineering, projects, and construction for the Florida Power & Light Co.

And I'm also told that Mr. Dager is the person who managed the construction of St. Lucie No. 2 for Florida Power & Light and brought it in on time and within the budget.

So both of you are very prestigious gentlemen.

Welcome. We have your testimony. You may proceed as you wish, and your entire statement will be made a part of the record.

Mr. Dilworth, we're happy to have you here this morning from Knoxville. How's the snow?

STATEMENT OF GEORGE F. DILWORTH, ASSISTANT MANAGER, TENNESSEE VALLEY AUTHORITY, KNOXVILLE, TENN.

Mr. DILWORTH. We have a little bit down there, about 4 inches.

Mrs. LLOYD. We're glad to be up north, a little further north, where we don't have the snow this morning.

Mr. DILWORTH. Madam Chairman, my name is George Dilworth, and I am assistant general manager, technical, for the Tennessee Valley Authority.

I am very glad to be here today to testify before your Subcommittee on Energy Research and Production. TVA is encouraged that Congress is carefully considering ways to preserve the power supply options through nuclear fission along with solar energy and fossil fuels for future generations of Americans.

There are three basic power supply options that we at TVA have seen that we have to meet our responsibility, and these are: renewable energy sources, which would include conservation, solar, load management, and so forth; fossil fuel and hydro generation; and nuclear power.

There are real risks in the fossil fuel and nuclear options, and there's an urgent need for a stronger research and development effort for the renewable options.

In renewables, we at TVA have already made real strides in conservation and are expecting a significant contribution from solar and load management. These methods, of course, are the most economical way to supply electricity since they allow us to utilize capacity that we already have on our system, plants that are already built and are operating.

Future use of one of our region's major resources, our forests, as a means to provide energy in a variety of ways is also part of our strategy at TVA. We are strongly committed to these methods, but we also wish to keep central station options open in case they are needed.

Therefore, at present these methods cannot be relied on to the exclusion of other options. We, therefore, urge the subcommittee to give the highest priority to strengthen the research and development programs to improve these renewable sources which may provide an everlasting source of environmentally superior and economic energy.

We recognize that the supply option using fossil and hydro generation faces significant uncertainties largely because of environmental impacts. For example, we know that there are real problems with acid rain and recent reports and studies on the CO_2 greenhouse effect hold forth a risk that, sometime in the future, generation by fossil fuels may have to be limited. We have virtually reached the physical limit of hydroelectric development.

Using the supply option of nuclear power with current designs is becoming more and more difficult and complex and is requiring vast amounts of resources in talent and money which are severely straining the utility industry.

In our region we are committed to carry out or support research, development, and demonstrations on all three power supply options because of the potential inherent in all three. We can't simply or solely depend on any one of them.

TVA is involved in modest efforts to preserve and broaden the choices for the nuclear option for the future. This includes work on the advanced light water reactors, the high temperature gas-cooled reactor, and the Secure-P or PIUS concept reactor. We are also working diligently to improve performance of the present generation light water reactors we have under design, construction, and operation. The funding for this work has come from TVA's power revenues and a significant amount of these funds go through the overall Electric Power Research Institute activities. But TVA ratepayers cannot pay for major national research and development efforts.

We have little doubt that if you start with a "new sheet of paper," reactors, either large or small, can be made safer by preventing core damage during the worst case accident scenarios, and, by so doing, the public would be exposed to less risk as a result of proximity to a nuclear plant.

We heartily endorse the goal of a safer reactor for new reactor designs. Indeed, we believe that any programs for new alternative reactors must encompass even broader overall goals. We realize that the ultimate customers of whatever reactors are developed are the utilities. Therefore, we must have a program which, for lack of a better term, I will call a program for "risk abatement" from the utilities' viewpoints.

I believe that before utilities will again begin investing in reactors for their supply options they must have a clear and well-defined understanding of the various risks they face. This means that a research, development, and demonstration program must first make a careful study on how these risks can be reduced.

For example, there must be more certainty and a much shorter time period from identification of needed capacity and the online schedule for that capacity. There should be more stability in design and less complexity in the requirements which must be met.

I envision that a task force of representatives from the utilities would provide DOE and the NRC, or whoever is designated by Congress, with criteria as definitive for risk abatement as possible. I'm using this word "risk abatement" in its broadest sense. A complete program through demonstration for the most promising alternatives could then be developed.

These programs should be accompanied by feasibility studies which give some idea of what the eventual cost of power from that alternative reactor would be. This is of the utmost importance if the nuclear supply option is to remain open. I believe that the utility industry will get behind new reactor research, development, and demonstration if they can clearly see a promise for real "risk abatement" for the public and for them as utilities.

TVA is now studying the alternative reactor types being considered by this subcommittee, and at the present time we believe both the HTGR and the PIUS, the Secure-P or PIUS, alternatives hold forth promise as inherently safe reactors. We will be studying all the options more carefully in the coming year.

There has been quite a bit of debate recently concerning the reactor size of possible new alternatives. We feel that it would be unwise to assume that only small reactors will be needed in the future. There may be a market in the future for both small and large reactors.

We are a member of the Gas Cooled Reactor Associates, GCRA, and feel that the 2,240-megawatt thermal integrated design holds promise as a lead plant design for a large HTGR. We also believe that there is promise that a smaller modular design of an HTGR, if designed properly with utility input, can be economical if the risk abatement I spoke of earlier can be realized.

There are also possibilities to design an HTGR of a mid-size which has the same safety features of the small modular size.

TVA is involved in a preliminary way with ASEA-ATOM in reviewing the concept and basic design documentation and cost estimate methods of the Secure-P, PIUS, reactor. We have also built a small, tabletop model to demonstrate the thermal interface and any mixing problems which might occur. We plan to follow, in a modest way, the progress of work in these alternative types and to participate when we think it's appropriate.

Madam Chairman, we appreciate the opportunity to present our views here today, and we must say that the work of this subcommittee is vital to the long-range energy supply for this Nation.

[The prepared statement of Mr. Dilworth follows:]

TESTIMONY OF GEORGE F. DILWORTH
ASSISTANT GENERAL MANAGER
TENNESSEE VALLEY AUTHORITY
BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
FEBRUARY 7, 1984

Madam Chairman, my name is George Dilworth and I am Assistant General Manager (Technical) for the Tennessee Valley Authority. I am very glad to be here today to testify before your Subcommittee on Energy Research and Production. TVA is encouraged that Congress is carefully considering ways to preserve power supply options through nuclear fission along with solar energy and fossil fuels, for future generations of Americans.

There are three basic power supply options which we have to meet this responsibility:

- Renewable energy sources (this includes conservation, solar, load management, etc.);
- fossil fuel and hydro generation;
- nuclear power.

There are real risks in the fossil fuel and nuclear options and an urgent need for a stronger research and development effort for the renewable options.

In renewables, we have already made real strides in conservation and are expecting a significant contribution from solar and load management. These methods, of course, are the most economical way to supply electricity since they allow us to utilize capacity that we already have on our system, plants that are already built and operating. Future use of one of our region's major resources, our forests, as a means to provide energy in a variety of ways is also part of our strategy. We are strongly committed to these methods but we also wish to keep central station options open in case they are needed. Therefore, at present, these methods cannot be relied on to the exclusion of other options. We, therefore, urge the Subcommittee to give the highest priority to strengthen the research and development programs to improve these renewable sources which may provide an everlasting source of environmentally superior and economic energy.

We recognize that the supply option using fossil and hydro generation faces significant uncertainties largely because of environmental impacts. For example, we know there are real problems with acid rain and recent reports and studies on the CO_2 greenhouse effect hold forth a risk that sometime in the future generation by fossil fuels may have to be limited. We have virtually reached the physical limit of hydroelectric development.

Using the supply option of nuclear power with current designs is becoming more and more difficult and complex and is requiring vast amounts of resources in talent and money which are severely straining the utility industry.

In our region we are committed to carry out or support research, development, and demonstrations on all three power supply options because of the potential inherent in all three. We can't depend solely on any one of them.

TVA is involved in modest efforts to preserve and broaden the choices for the nuclear option for the future. This includes work on the advanced light water reactors, the High Temperature Gas Cooled Reactor, and the Secure-P or PIUS concept reactor. We are also working diligently to improve performance of the present generation light water reactors we have under design, construction, and operation. The funding for this work has come from TVA's power revenues and a significant amount of these funds go through the overall Electric Power Research Institute activities. But TVA ratepayers cannot pay for major national research and development efforts.

We have little doubt that, if you start with a "new sheet of paper," reactors, either large or small, can be made safer by preventing core damage during the worst case accident scenarios and by so doing the public would be exposed to less risk as a result of proximity to a nuclear plant.

We heartily endorse the goal of a safer reactor for new reactor designs. Indeed, we believe that any programs for new alternative reactors must encompass even broader overall goals. We must realize that the ultimate customers of whatever reactors are developed are the utilities; therefore, we must have a program which, for lack of a better term, I will call a program for "risk abatement" from the utilities' viewpoints. I believe that before utilities will again investing in reactors for their power supply option they must have a clear and well-defined understanding of the various risks they face. This means that a research, development and demonstration program must first make a careful study on how these risks can be reduced. For example, there must be more certainty and a much shorter time period from identification of needed capacity and the online schedule for the capacity, more stability in design, and less complexity in the requirements which must be met. I envision that a task force of representatives from the utilities would provide DOE and the NRC, or whoever is designated by Congress, with criteria as definitive for risk abatement as possible. A complete program through demonstration for the most promising alternatives could then be developed.

These programs should be accompanied by feasibility studies which give some idea of what the eventual cost of power from that alternative reactor would be. This is of the utmost importance if the nuclear supply option is to remain open. I believe the utility industry will get behind new reactor research, development and demonstration if it can clearly see a promise for real "risk abatement" for the public and for it.

TVA is now studying the alternative reactor types being considered by this subcommittee, and at the present time we believe both the HTGR and the Secure-P (PIUS) alternatives hold forth promise as inherently safe reactors. We will be studying all the options more carefully in the coming year. There has been quite a bit of debate recently concerning the reactor size of possible new alternatives. We feel that it would be unwise to assume that only small reactors will be needed in the future. There may be a market for both small and large reactors. We are a member of the Gas Cooled Reactor Associates (GCRA) and feel that the 2240 MW integrated design holds promise as a lead plant design for a large HTGR. We also believe there is promise that a smaller "modular" design of an HTGR, if designed properly with utility input, can be economical if the "risk abatement" I spoke of earlier can be realized. There are also possibilities to design an HTGR of a mid-size that has the same safety features of the small modular size. TVA is involved in a preliminary way with ASEA-ATOM in reviewing the concept and basic design documentation and cost estimate methods of the Secure-P (PIUS) reactor. We have also built a small, table-top model to demonstrate the the thermal interface and any mixing problems which might occur. We plan to follow in a modest way the progress of work in these alternative types and to participate when we think it is appropriate.

Madam Chairman, we appreciate the opportunity to present our views here today. The work of this Subcommittee is vital to the long-range energy supply for this nation.

Mrs. LLOYD. Thank you very much, Mr. Dilworth.
Mr. Dager?

STATEMENT OF H. JAMES DAGER, VICE PRESIDENT OF ENGINEERING, PROJECTS AND CONSTRUCTION, FLORIDA POWER & LIGHT CO.

Mr. DAGER. Thank you, Madam Chairman.

I'm H. James Dager, vice president for engineering, project management and construction, Florida Power & Light Co.

The Florida Power & Light Co. recently completed and placed into commercial operation our fourth nuclear unit, St. Lucie Unit 2. We are proud of the accomplishments of our project team, and we are thankful for the accolades that we have received, especially the plaudits from the chairman of your committee, Congressman Fuqua, that were published in the Congressional Record. I also found out that the NRC reads the Congressional Record through that.

We feel that we proved that nuclear powerplants can be built on schedule to provide safe, economical power with little impact on the environment.

As an aside, the St. Lucie Unit 2 went into commercial operation the first week in August. Since that time, it has attained a capacity factor of 86 percent. We're heading for 90 percent in March. We have saved our customers over $110 million in differential fuel costs, and we have displaced 5.5 million barrels of oil just since August.

We are not, however, ready to tackle a new nuclear unit. We do strongly believe that it would be a grave mistake for the Nation to abandon nuclear power, and we at FPL, in particular, want to have the nuclear option available in the mid- to late-1990's for new powerplants or repowering of old powerplants, particularly our 400-megawatt oil-fired units.

We very much prefer to locate our powerplants close to the loads we serve. Our major electrical loads occur in Dade County and the Gold Coast of Florida. We are presently holding the South Dade site, which is approximately 20 miles south of Miami and 10 miles east of Homestead. We are convinced that the only power source that we could license for this site is the high temperature gas reactor.

With the Everglades National Park to the west and Biscayne National Monument and Elliott Key State Park to the east, the possibility of locating coal units at the South Dade site appears to be very remote. Oil- or gas-fired units are also not possible. The high temperature gas reactor, with significantly lower radioactive releases and significantly higher thermal efficiencies, calling for less makeup water, appears to be the only possible candidate for South Dade.

Recently there has been much enthusiasm generated for the modular HTGR. We share that enthusiasm as this smaller HTGR offers some attractive features such as:

We could more finely tune our capacity additions to the load growth. As the load growth drops off, we need to look at smaller units that will meet the load on a yearly basis.

At the same time, this would reduce the amount of capital at risk before the revenue flow starts.

It would allow more factory input with the attendant possibility of factory certification, so that less possibility of mishaps in the field erection would occur.

It also would permit the possibility of residual heat removal by passive systems such as radiation, conduction, and natural convection with no fission product release.

There would be more markets in developing countries and for cogenerators, process heat users, and repowering of older powerplants. This, in turn, encourages standardization and mass production techniques which will lower costs for everybody.

With the inherent safety features, the operation of the plant by computer becomes a very real and attractive possibility.

But before we get carried away with enthusiasm, let's remember that we don't want to fall victim to the inverse law of ignorance; that is, the less that is known about a technology, the more attractive it becomes. Before a demonstration modular HTGR is built, some serious technical and economic issues need to be addressed. For example:

Is it necessary to vent the reactor coolant to the atmosphere under certain depressurization conditions?

Two, can the modules be built without containment?

Can the modules be operated by a computer from one control room with reduced number of operators/observers?

Is it necessary to have an emergency evacuation plan, with the attendant sirens and emergency offsite facilities and safety assessment system, et cetera?

Can the security requirements be simplified? If we have to have 300 guards per module, forget it.

It becomes clear that we are facing a chicken and egg situation. We cannot make a good cost estimate or risk assessment until both technical and regulatory issues are resolved. This means that the Nuclear Regulatory Commission should be closely involved from the very beginning of this effort. Since the design for the modular HTGR is, at this time, very conceptual, one way to get this early involvement is to proceed with an NRC design review of the larger HTGR while the design of the modular HTGR is developed.

In order for nuclear power to be reborn, it is necessary to go back to the drawing board and start over with a simpler reactor with passive decay heat removal systems, little or no radioactive releases, and less radiation exposure for the plant workers. We think the HTGR can meet these objectives. As a member of the Gas Cooled Reactor Associates, we feel that we can provide valuable input and assistance in these efforts and request that we be kept involved.

The nuclear utilities are no longer naive. We have undergone our baptism in fire, and we will not accept, without severe scrutiny, what is presented as the next generation of safe, reliable nuclear powerplants by architects/engineers, constructors, manufacturers, or the Federal Government.

Thank you.

[The prepared statement of Mr. Dager follows:]

STATEMENT TO THE COMMITTEE ON
SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES
CONGRESS OF THE UNITED STATES

H. James Dager
Vice President for Engineering, Projects & Construction
Florida Power & Light Company

Florida Power & Light Company recently completed and placed into commercial operation our fourth nuclear unit, St. Lucie Unit 2. We are proud of the accomplishments of our project team and we are thankful for the accolades that we have received, especially the plaudits from you, Mr. Chairman, that were published in the Congressional Record. We feel that we proved that nuclear power plants can be built on schedule to provide safe, economical power with little impact on the environment.

We are not, however, ready to immediately tackle a new nuclear unit. We do strongly believe that it would be a grave mistake for the nation to abandon nuclear power and we at FPL want to have the nuclear option commercially available in the mid to late 1990's for new power plants or repowering of old plants.

We very much prefer to locate our power plants close to the loads we serve. Our major electrical loads occur in Dade County and the Gold Coast of South Florida. We are presently holding the South Dade site which is approximately 20 miles south of Miami and 10 miles east of Homestead. We are convinced that the only power source that we could license for this site is the High Temperature Gas Reactor. With the Everglades National Park to the west and Biscayne National Monument to the east the possibility of locating coal units at the South Dade site appears to be very remote. Oil or gas-fired units are also not possible. The high temperature gas reactor, with significantly lower radioactive releases and significantly higher thermal efficiencies appears to be the only possible candidate for South Dade.

Recently there has been much enthusiasm generated for the modular HTGR. We share that enthusiasm as this smaller HTGR offers some attractive features such as:

1. More finely tuned capacity additions to load growth.
2. Reduce the amount of capital at risk before revenue flow starts.
3. More factory input with the attendant possibility of factory certification so less possibility of mishaps in field erection.
4. The possibility of residual heat removal by passive systems such as radiation, conduction, and natural convection with no fission product release.

5. More markets in developing countries and for co-generators, process heat users, and repowering of older power plants. This in turn encourages standardization and mass production techniques which will lower costs for all.
6. With the inherent safety features, the operation of the plant by computer becomes a very real and attractive possibility.

Before we get carried away with enthusiasm, let's remember that we don't want to fall victim to the inverse law of ignorance; i.e., the less that is known about a technology the more attractive it becomes. Before a demonstration modular HTGR is built, some serious technical and economic issues need to be addressed. For example:

1. Is it necessary to vent the reactor coolant to the atmospher under certain depressurization conditions?
2. Can the modules be built without containment?
3. Can the modules be operated by a computer from one control room with reduced number of operators/observers?
4. Is it necessary to have an emergency evacuation plan, sirens, etc.?
5. Can the security requirements be simplified?

It becomes clear that we are facing a chicken and egg situation; i.e., we cannot make a good cost estimate or risk assessment until both technical and regulatory issues are resolved. This means that the Nuclear Regulatory Commission should be closely involved from the very beginning of this effort. Since the design for the modular HTGR is, at this time, very conceptual, one way to get this early involvement is to proceed with an NRC design review of the larger prismatic-core HTGR (840 Mwe) while the design of the modular HTGR is developed.

In order for nuclear power to be reborn, it is necessary to go back to the drawing board and start over with a simpler reactor with passive decay heat removal systems, little or no radioactive releases, and less radiation exposure for plant workers. We think the HTGR can meet these objectives. As a member of the Gas Cooled Reactor Associates, we feel that we can provide valuable input and assistance in these efforts and request that we be kept involved.

The nuclear utilities are no longer naive - we have undergone our baptism in fire - and we will not accept, without severe scrutiny, what is presented as the next generation of safe, reliable, nuclear power plants by A&E constructors, manufacturers, or the Federal Government.

Mrs. Lloyd. Thank you very much, Mr. Dager.

Mr. Dilworth, yesterday Congressman Fuqua and I held a press conference on the OTA report. And one of the reporters sort of got me in the position of being a representative of TVA, which I certainly don't profess to be nor would I want to be. But she said, "Now why on earth, when TVA has cancelled three major nuclear plants, would they want to invest in the concepts that you're discussing today?" I did a pretty good job, I think, of answering for you, but I'd like your comments today for the record.

Mr. Dilworth. Well, the purpose of TVA cancelling four nuclear units and deferring four others was a business decision that we were faced with based on the load growth changes that occurred in our region in the late seventies, and that we are projecting on out until the year 2000.

As it turns out now, even though we were seeing load growth of 7 and 8 percent through the sixties and early seventies, our load has basically been flat since about 1976.

We have units now under active construction, ending with our Bellefonte Unit 2, which means there's four more units that we have under active construction. The last of those units will go online in the early nineties. At our highest load growth projection, we won't need any other capacity until late nineties or about 2000.

So our decision to defer and cancel was really based on the fact that there's no customers for that power. You're well aware of the fact that one of our most significant loads, of course, was DOE enrichment loads, and those are going down as well. So we were caught in a situation of the decline in the need of enriched fuel for the total industry, and it hit us doubly hard as well.

Mrs. Lloyd. Well, she was commenting on your interest in the modular HTGR and the PIUS reactor.

Mr. Dilworth. Well, our interest in these new reactor types basically, as I said a while ago, we really believe that we have to depend on all three of the available methods to produce power in the future, and it would be very shortsighted for anyone that has a responsibility—our responsibility goes further than just to our stockholders, which in this case would be the citizens of this country. Our responsibility is to produce the power for the people and the development of our region. We're going to have available power. The question is how we're going to produce it. It would be shortsighted to say that we want to just completely forget about fission energy.

Innovation in this country and the greatness of its technology didn't occur by people just throwing aside concepts that had promise, and we strongly feel that way. We feel that these inherently safe, in the term that I've heard it discussed here today, that you essentially have no core damage due to natural physical arrangement of the reactor and its ability to cool itself naturally, is something that holds forth promise that we encourage.

We're not at all saying that what we have now is unsafe. We're just saying that in the future things have got to be simpler. It's got to call on less resources, total resources, that would be dollars, manpower, talent, and no accident could render your plant in a condition that it would be a loss to you as an investor.

Mrs. Lloyd. Would you comment a little bit further on the concept we have been talking about this morning, the power certification for reactor designs, one that would be similar to the FAA approach to air worthiness?

Mr. Dilworth. I think that is a very viable approach and something that really will have to happen if the utilities are to begin ordering again. They have got to have assurance that when they've bought something they know what they've bought, and it's not going to take them 10 to 15 years to redesign it three or four times and to reconstruct it two or three times.

So this power worthiness I think is a theme that I'd like to see advanced.

Mrs. Lloyd. Thank you very much.

Mr. Dager, since you so successfully managed the construction of St. Lucie No. 2, which was completed, as we said, on time and within the budget, what was so unique with your operation? Why is it this just can't be done again? Why is it that most utilities take from 10 to 12 years in this country?

Mr. Dager. One, we had total management commitment to complete St. Lucie 2 within the schedule and under budget or on budget and within what we described we would build in the FSAR, the final safety analysis report.

At the same time, I have to add, we canceled two 1,140-megawatt electrical units at South Dade. To meet this commitment, we had to conserve our cash. Our stock was selling below book value, and stockholders take a very dim view of you continuing to sell stock below book value, diluting the earnings per share.

So we canceled South Dade after we made a risk assessment on where the nuclear industry was going. This was in 1977.

We also deferred fossil units in order to conserve cash. We made the commitment to complete St. Lucie 2. This commitment came from the chairman of the board on down.

There are lots of other—in fact, I'm giving a talk tomorrow on how we did it. That would take a long time, though. There are about 11 other factors that we considered important.

Mrs. Lloyd. Is there any further comment that you would like to make, Mr. Dilworth and Mr. Dager, on our hearings today?

Mr. Dilworth. I would agree with what Mr. Dager said about the potential for modular reactors as being a means to replace the steam supply for plants that have maybe been built in the fifties and early sixties that have smaller size but steam conditions for the balance of plant, very similar to what this HTGR steam supply would produce.

I'm a little bit concerned about the smallness of the size of the modular reactor that we hear talked about, because I think that you're going to be needing reactors in a range of, say, 150-megawatt electric up to about 400, in that range.

Mrs. Lloyd. So you agree with Mr. Dager we should go ahead with NRC licensing procedures for the larger HTGR?

Mr. Dilworth. Yes, I do.

Mrs. Lloyd. You know, I think that we have failed to take into account the fact that a lot of our plants are going to retiring before long. And we're not only losing our capacity to produce power, but, as Mr. Trauger pointed out in his work in our BRET program, that we cannot lose our design team and our engineers that are working on the programs that are in place.

When we see that there are no new orders being placed for reactors, we have to face realities. Not only will we need new capacity, but we are also going to have to replace retiring plants. And we must have not only the technology in hand, but we have to have the scientists and the engineers in place, also, so that we can move forward and not be lost without the capacity for producing energy in this country, which is not only essential for our economic prosperity but for our military applications as well.

I certainly appreciate your input, and we'd also appreciate hearing from you with other thoughts that you might have that you would like to address to this committee throughout this year as well.

Thank you very much.

We thank all of our witnesses.

This committee will stand in recess until 1 o'clock this afternoon.

[Whereupon, at 11:30 a.m., the subcommittee recessed, to reconvene at 1 p.m. the same day.]

AFTERNOON SESSION

Mrs. LLOYD. The Subcommittee on Energy Research and Production will come to order.

Good afternoon, ladies and gentlemen. Although I do not share the pessimism of this week's Time magazine which asks the question, "Is nuclear power bombing out?", I do think that the nuclear option is at present heavily beleaguered. This is one of the reasons I held a press conference yesterday with Chairman Fuqua to highlight the release of the OTA report, "Nuclear Power in an Age of Uncertainty." I believe that the OTA report confronts the problem head-on and offers a Federal blueprint for improving the nuclear climate. And I am also very delighted today that an old friend, Dr. John Gibbons, is here today to summarize this very valuable report.

We should recognize that, unlike previous budget submissions of the Reagan administration, this year's budget has a shortfall in the nuclear fission R&D request, even as compared to nonnuclear programs. In fact, the Federal funding for nuclear fission R&D has dropped by about 50 percent since the last Carter budget. Although one chief reason for this reduction has been the off-budget funding of the nuclear waste program, this decrease is also due to heavy budgetary pressures on fission R&D from the OMB and of course the CRBR.

As I said this morning to the outside witnesses, it is time for a fresh start in nuclear research and development. I believe that both the OTA report and the CRS study suggest a variety of fresh approaches which should be given very serious consideration. The committee role as an authorizing body is limited to R&D programs; and although we do have concerns about the regulation of nuclear power, the uncertainty of licensing, and so forth, the technological arena is where we must focus our attention. We also intend to utilize the talented industrial infrastructure which exists for supporting nuclear programs, while allowing for a redistribution of tasks.

We have also encouraged the DOE to thoughtfully restructure the breeder program which no longer has the focus of a plant commitment which CRBR provided. Chairman Fuqua and I have made it clear that we would prefer to emphasize innovative designs for breeder reactors to provide a strong program focus.

So we must broaden the nuclear fission program overall so that it becomes a true advanced reactor development program which addresses intermediate options in terms of reactors that will meet the marketplace test of the nineties and the early part of the next century. Dr. Gibbons will discuss the OTA study recommendations on alternative reactor concepts, as well as the workshop which concentrated on such concepts.

And Dr. Behrens of the CRS will then tell us about his study which explored the advantages of small reactors in today's economic and regulatory climate. Both of these efforts were initiated over 1½ years ago and are proving to be extremely timely in the sense that we do have the opportunity for a fresh start.

Dr. Gibbons, would you please proceed?

Dr. Gibbons is also accompanied by Dr. Alan Crane, who did such a fine job on the report and who we were very happy to have with us yesterday for our news conference, as well.

Please proceed.

STATEMENT OF DR. JOHN H. GIBBONS, DIRECTOR, OFFICE OF TECHNOLOGY ASSESSMENT, ACCOMPANIED BY ALAN CRANE, SENIOR ASSOCIATE

Dr. **Gibbons**. Thank you, Madam Chairman, for inviting us to be with you today.

I would like to submit my written testimony for the record, if that is permissible, and speak only from notes.

Mrs. **Lloyd**. We're having microphone problems up here. Without objection it will be made a part of the record, and you may proceed and summarize as you wish.

Dr. **Gibbons**. Thank you very much.

I think it's important for us to keep in mind several things largely independent of the nuclear issue that have strongly affected the electricity sector in our energy economy. I would mention three things.

First of all, there was a relatively sudden discovery of cost-effective ways to reduce demand growth via increased efficiency about a decade ago, and this had dramatic and pervasive impact on electricity vendors and the utilities. There was a change from a high growth industry to a low growth industry that occurred over a period of only a few years. Now, there is lots of evidence that such improvements in electricity productivity will continue for some years to come, even if electricity prices rise no further. Now, this is an important element in any planning about the electricity sector.

The second point is that the momentum of powerplant construction carried the system capacity far past its optimum and it created what one might call an electricity bubble. That can be good news as well as bad news, as we shall see. Now, that situation, combined with the economic impacts of the oil price shocks, knocked the props from under the earlier perceived imperative for rapid expansion of our generating capacity.

The third observation I would make is that it is now particularly difficult to predict future demand for electricity. And this is especially tough on the supply options that are characterized with large capital costs and also large leadtimes.

Again, these are all independent of nuclear; they are general observations of very important dynamics within the electricity sector. And there are a couple of other things that have particular relevance to the nuclear option that I think we should also review.

First, the light water reactor has turned out to be, in retrospect at least, a more complex, exacting, and—indeed—unforgiving technology than was earlier perceived by many of the suppliers and the utilities. As a consequence, the requisite attention and investment in design, management, and in quality control weren't made in some instances. And this has come back to haunt us.

Well, it led to problems; for instance, accidents, evidence of shabby work, poor operations. That in turn led to increased regulatory scrutiny, and that in turn led to more problems of cost and delay that we now face. And as a consequence, there was a loss or an erosion of confidence on the part of the investors, the owners, and the public; and there was financial loss and even the loss of an important competitive edge that was once perceived.

The second point I would make that has special relevance to the nuclear option is that we've been going through a period of high inflation, particularly in the area of capital construction. Now, when that is combined with the deferred return on investment in that capital construction, that greatly exacerbates the financial problems faced by the nuclear utilities.

Public confidence, then, in nuclear power was steadily eroded by various events—confidence in safety and cost advantage have now largely disappeared; utilities have been walking away from nuclear powerplant construction not just because of lower demand forecasts, but because of basically altered perceptions about the attractiveness of nuclear power compared to other options.

On the other hand, Madam Chairman, as you well know, there is clear, present, hard evidence that given certain circumstances that are not that unusual or that unobtainable, nuclear powerplants can, today, be a very reliable and cost-competitive option, even if one ignores the several other important positive benefits of nuclear power compared, for instance, to coal or oil-fired plants with respect to environmental emissions.

Well, given these circumstances, then, what can be said? One might say, well, drop the option; but the energy is such a ubiquitous input to the provision of goods and services in our economy and to the maintenance of health and environmental quality, and our energy options, in fact, are so few that abandoning any option seems to be a foolish one at this point in time. But without a change in present course we may be, de facto, taking that choice.

Now, if we decide that the maintenance of the option is important, what is to be done? And that, of course, was the subject of the study we carried out for you. And I think the answer lies generally in taking steps to reduce uncertainty; uncertainty about safety, and about financial uncertainty which, in turn, relates to uncertainty about the future path of demand as well as to the cost and reliability of supply.

Now, this must happen—this reduction of uncertainty must happen if we hope to see confidence and support restored among the various publics that are associated with the electricity sector.

One very large area of potential importance is in the area in the jurisdiction of this committee, namely, research and development. I summarize, beginning near the bottom of page 5 of my testimony to you, some examinations we made of several areas in the area of research and development. Let me briefly summarize those for you.

First of all, I would say we set certain goals—the goal of safety, making our powerplants more safe; less costly; and immersed in an aura of less uncertainty than presently exists. How do you do this? One way to do it is to make them inherently safer, by the basic design of the system. Another way to go after these goals is to think about smaller unit size. If you can go to smaller unit size without unacceptable penalty, it enables one to think about standardization, about factory construction and the concomitant gains one could have in quality control and cost, and also might enable one to be led toward shorter time constants in the system which, in turn, helps cost.

We looked at several concepts and activities—the advanced light water reactors; as you know, Westinghouse and General Electric both have been advancing that state of the art in the private sector as well as Government support. There are new arrangements between these two companies and companies in Japan which look very encouraging. In other words, there is a lot of self interest already imbedded in the marketplace to advance that already maturing technology.

We also looked at high temperature gas reactors. There, there is less industrial experience but we are attracted by the high efficiency of such reactors and the fact that they have a large, inherent safety margin. They are much more forgiving, as it were, than the traditional light water reactors. I have to give a caveat, however, that we don't have that much experience with these in full scale, the HTGR's, and therefore estimates of cost and reliability are necessarily much larger than one can say for the LWR's.

The U.S. focus on high temperature gas reactors has been in the large size reactor, some of them remarkably large, but we feel that there is some very interesting opportunity in the smaller or modular size HTGR that would be in, perhaps, the 100-megawatt class rather than 10 or more times that size. The economies of this lower scale are still speculative but we believe a good deal of attention is merited on those systems.

And then the third kind of reactor that we examined in our workshop and in our report to you, Madam Chairman, is the so-called PIUS—which doesn't mean more holy, it means "process inherent ultimately safe" reactor concept. The most interesting that I've seen is the Swedish concept in which the core and critical components of the reactor are immersed in a very large pool of water designed so that if any accident goes wrong, you can basically go away and come back a week later and see what maybe you ought to do about it. It doesn't have the very short time constant and necessary engineered response that is required in the LWR's. So we feel that this is enormously potentially more resilient to accidents including, incidentally, sabotage.

And then, finally, we looked at liquid metal reactors. Of course, it's a technology that most people associate with breeders; but liquid metals have a number of very interesting advantages over water in terms of coolants; in terms of design, they're easier to design for passive cooling and the like. We think there are some important opportunities here that are well worth some examination.

And finally I would mention, simply on the side, that the evidence now is so strong that a miscalculation in putting into place an electricity-generating system—uncertainty is so important for those that require longer times to put into place—that in terms of research it is also of merit to think more carefully, to do more research on how to analyze the very basis or nature of demand for electricity, and also how the dynamics of that demand can change under changing circumstances.

In summary, Madam Chairman, if the nuclear power option is deemed worth holding to, there are several steps, any of which could help.

First, making what we have work very well, institutionalizing higher levels of quality; not only in construction, but in the operation of reactors. And there is much afoot, of course, and has been going on in the past several years, in this regard; not that we haven't done all that we could do.

Second, make more productive use of the concerned public in shaping this technology and putting it to work.

Third, make more efficient and predictable regulation, which has introduced an element of uncertainty and, therefore, cost into the system. It's not been perfect; we feel it, and we present some ideas about this, but we also feel that changes in the regulatory structure could be made without a legislative change but rather by administrative changes.

Finally, but far from least, research and development. Some of the research and development relates to things that simply can't show up as commercial products before the end of the century, but that's not far off and it might be a good time to aim for.

To close, we judge that no single one of these four steps will turn the trick; indeed, all steps taken together could make a very enormous difference, and this is what is likely required.

Thank you.

[The prepared statement of Dr. Gibbons follows:]

Testimony of Dr. John H. Gibbons, Director
Office of Technology Assessment
Before
Subcommittee on Energy Research and Production
House Committee on Science and Technology

February 7, 1984

Thank you Madame Chairman for the opportunity to testify before the Subcommittee today. With me is Alan Crane, Senior Associate at OTA and the project director of our study, Nuclear Power in an Age of Uncertainty, which was released by the Committee yesterday.

As most people know, nuclear power is in a state of crisis. In the past few weeks we have seen the denial of an operating license to the Byron plants by the Atomic Safety Licensing Board of the NRC, the deferral of construction of the Marble Hill plant because of high costs, and the announcement that the Zimmer plant will be converted to coal even though it is 97% complete. The future of other plants under construction or awaiting operating licenses is in serious doubt. With no hint of a new domestic order over the next few years the prospects for nuclear power in this country seem bleak.

What has been the cause of this situation? A major contributor has been the substantial slowdown in demand growth for electricity since 1973 which left many utilities with too much capacity on order. The very high interest rates which hit the country over the same period added greatly to the burden because of the capital intensiveness and long construction time of nuclear power plants. In addition to these economic factors there are many problems specific to nuclear power that added to its difficulties.

The industry has itself to blame for many of these problems. In hindsight it is clear that the technology grew too fast, both in the size of the units and the numbers ordered. The present generation of reactors suffered from being derived from an immature technology and an underestimation by some utilities and their contractors of the difficulty of managing it. While the operating record of U.S. plants has generally been accident free - with a few notable exceptions - there has been great variability in construction times and capacity factors. Many utilities have encountered difficulities, some of which have been serious enough to have safety implications and severe financial consequences.

Costs of nuclear power plants have been escalating at a dramatic pace. While this is due in part to general inflation and new regulatory requirements, there has also been substantial variation in costs between plants to indicate that other factors play a role. Most important appears to be the differences in the experience and ability of utility and construction managers.

Changing regulatory requirements have also added to cost, delays and complexity. Many of the changes in regulatory requirements over the last several years have been the result of improved analysis as the technology matured. Others were due to poor quality control during construction. The process by which changes in reactor design have been imposed along with many of the aspects of the licensing process itself, however, have lead to increasingly unpredictable regulation which does not necessarily assure safety and efficiency.

All of these problems have added up to a crisis in confidence about the option. Currently nuclear powerplants present too many financial risks. The confidence of the public, investors, rate and safety regulators, and the utilities themselves has been severely shaken and will not be restored easily. Unless this trust is restored, nuclear power will not be a credible energy option for this country.

If these problems and the risks they create were inherent to nuclear power, there would be little concern for its demise. Some utilities, however have clearly demonstrated that the difficulties with this technology are not insurmountable. Nuclear plants which have been built, operated and maintained well are generally safe, reliable and economical sources of energy. Examples are the Calvert Cliffs and St. Lucie plants which have lifetime capacity factors in excess of 74 percent. Further there are reasons why it could be important to have an improved nuclear option in the future. Future electricity demand is very uncertain, and that uncertainty takes its highest toll from power generation technologies that require long lead times. Depending on demand growth and on retirement schedules for existing power plants, anywhere from zero to 400 new, large powerplants will need to be ordered by 1994 to meet new demand through 2005. Without nuclear power most would be coal-fired, with potiential impacts such as acid rain and carbon-dioxide-induced climatic changes that may prove unacceptable. Of course, there are other potential power sources which, along with load management, will play an increasingly important role over the next several years. We are currently analyzing these possibilities for the Committee. There are, however, many, significant economic uncertainties with the new technologies.

Therefore, if the Congress believes it is important to maintain a nuclear option, we need to ask what can be done to restore the public confidence so necessary for nuclear power to be a credible energy alternative? Many of the problems encountered on the present generation of reactors will not recur if new reactors are ordered because new designs will incorporate many changes made to correct old problems. It is not clear, however, whether this will be adequate to ensure safe, reliable operation. Our study points out several other areas where improvements are required. It is probable that all are necessary since none are sufficient by themselves.

First, construction and operation of safe and reliable nuclear powerplants demands a major commitment to excellence by the utility. Top utility executives must become more aware of the unique demands of nuclear technology. If a utility is unable to develop this commitment itself, organizations such as the NRC and the Institute for Nuclear Power Operations must take steps to see that these importment demands are met.

Second, the industry and the regulatory agencies should take steps to more effectively involve the public. A more concerted effort to be responsive to the substance of critics' concerns could reduce the acrimonious debate which contributes to public hostility. A necessary step in achieving public acceptance of nuclear power would be to improve management quality in construction and operation of nuclear powerplants and to expand efforts to improve the safety and reliability of the technology.

Third, the regulatory process needs to become more predictable and efficient. The primary objective of any regulatory revision, of course should be to ensure acceptable protection of public health and safety. Improved technology and management will also contribute to better regulation by reducing complexity. Encouraging preapproved standardized designs and developing analytical tools to evaluate proposed safety backfits are specific steps that could make licensing more efficient without sacrificing safety.

Finally, technological improvements can be very important for restoring the nuclear option. Technology improvements can make management of nuclear power less exacting by making powerplants inherently safer. This means building plants that rely more on simple, more nearly fail-safe systems to contain accidents than on those systems that require substantial human involvement and complex engineering. The former are characterized by passive elements such as reactor cores with large heat retention. Regulation could also become less cumbersome with standardized designs. Finally technology improvements that clearly demonstrate improved safety would go a long way toward restoring public confidence.

Because of the potential significance of technology improvements toward revitalizing the nuclear option and this Subcommitees interest in research and develcpement, I will spend the rest of my time discussing our study's findings about technology and, in particular, advanced reactor concepts.

The current mainstay of the industry, the light water reactor, is well on its way to maturity, and in many cases is operating quite well. There are still concerns over safety, however, and current designs are for plants that are so large and costly that few utilities can afford them. Accidents that can damage a reactor with grave financial consequences to a utility are much more likely than those accidents that pose a health risk to the public. Investors amd utilities are concerned about both possibilities, even though they are not expected to be frequent.

Given this situation, R&D could focus on efforts to make the LWR safer and less costly. Alternatively, or in parallel, R&D could be directed toward advanced reactors that would have advantages of greater reliance on inherent rather than engineered safety systems that would allow much more time to react to a potential accident than is possible for a conventional LWR, and would be more forgiving in case of error.

The reactors and reactor concepts that I will discuss are the advanced light water reactor, the high temperature gas reactor (HTGR), the heavy water reactor (HWR), the "process inherent ultimately safe" (PIUS) reactor, and the liquid metal reactor (not necessarily a breeder). It should be noted that all except the LWR introduce significant uncertainties about cost and regulation that could only be resolved by a demonstration plant. Without an extraordinary commitment, none, except the LWR, would be available much before the year 2000. If there are no commercial orders for reactors over the next 16 years, the industry may lose much of its ability to produce reactors of any kind. Regaining that expertise could involve significant startup expenses.

There are two important technical considerations that might be applied to any reactor R&D program: (1) standardized designs and (2) smaller size. Smaller nuclear plants would provide greater flexibility in utility planning - especially in times of uncertain demand growth - and less extreme economic consequences from unscheduled outages or accidents. The ability to build more of the subsystems in a factory rather than onsite could reduce construction costs, offsetting the lost engineering economies of scale. Moreover, a smaller reactor is likely to be easier to understand, more manageable to construct, and may be safer to operate. Federal R&D would probably be required to achieve designs that exploit the favorable characteristics of small reactors. Standardized plant designs could offer streamlined licensing, stabilized regulation, faster construction and less critical management needs. The help of the Federal government may be needed to develop and approve of a common design.

Advanced Light Water Reactors

Both Westinghouse and General Electric are currently designing advanced LWRs in conjunction with Japanese companies. New designs will incorporate many of the changes that have been retrofitted onto existing reactors. While these advanced reactors may have more inherent safety features than existing designs, they may not be viewed by the public as dramatically safer. In addition, the designs are for very large reactors, leaving problems of financing and overcapacity relatively untouched.

A Federal role in development of advanced LWRs could be based on the Nuclear Safety Research Development and Demonstration Act of 1980. Federal R&D emphasis could be to improve safety analyses such as probabilisitic risk assessment (PRA), to develop improved safety systems, and on improved operating procedures. Such a role could be a significant asset in both assuring safety and in assuring the public that it is being adequately addressed. Because utilities will be concerned about regulatory treatment and public acciptance of any new, advanced LWR, it is also conceivable that a demonstration will be required before any utility will be willing to order the next reactor of any type.

High Temperature Gas Reactor

Gas reactors offer impressive advantages of high efficiency, large safety margins and great resiliency to errors in operation. The latter two result from the large mass of the reactor core which heats up much more slowly than would an LWR following an accident. In addition, the temperature rise before damage occurs is much greater than for an LWR. For both of these reasons the time available before safety equipment has to operate is measured in hours rather than seconds - an inherent feature with obvious advantages. Unfortunately these reactors also have a reputation for high costs and poor reliability. There is considerable utility interest in the concept, however, and an industrial framework exists to develop a production capability.

The modular version is particularly attractive for safety. This is a very small - about 80 to 100 MWe - almost entirely factory fabricated reactor that could be passively cooled so effectively after an accident that no active systems would have to operate at all to maintain plant safety. The economics of this plant are very speculative because of the early stage of its development. It is likely that this design would be based on the German pebble bed reactor technology which is available to General Atomics, the single U.S. HTGR developer in the private sector. Because of its small size, it should be relatively easy to demonstrate and perfect.

Larger HTGRs have been the focus of the U.S. development program to date. Safety gains relative to the LWR would be less dramatic than for the modular HTGR, but still would be significant. If so, the HTGR's economic competitiveness could be greatly improved.

Process Inherent Ultimately Safe (PIUS) Reactor

The PIUS is a concept developed by ASEA-ATOM of Sweden in which an LWR-type core and other critical reactor components are submerged in a large pool of water. The pool is always available to flood the core and cool it in case of a malfunction without requiring the operation of pumps, valves or other active components, and assures adequate cooling for at least a week. Although still very early in development, the PIUS concept appears to be more resilient to all kinds of accidents, including sabotage, than any other concept, with the possible exception of the modular HTGR. In addition the PIUS concept to a great extent uses familiar LWR-type technology.

The major questions over the PIUS concept are the stability during normal operation (will the water enter the reactor when it isn't supposed to?), the maintainability of the system, much of which is under water, and the plant economics. These question will only be fully answered with a demonstration plant, but a modest program of R&D would give a good indication if the concept is worth pursuing. If the early R&D proves out, a prototype could be built and tested relatively quickly because of the general familiarity of the technology.

Commercialization of the PIUS concept in this country depends on the ability to use its safety characteristics to reduce costs. If, for example, a containment vessel is required as an additional safety barrier (as it is on the LWR) to eliminate the possibility of emissions of very low level radioactivity, then the PIUS would probably not be economically competitive with the LWR.

The PIUS concept does not offer significant new operating advantages to utilities aside from simplier and potentially safer operation. Thus it is not certain that even a successfully developed PIUS would have a role if improved LWRs are found acceptable, or if the more efficient HTGR is successfully demonstrated. Even if the PIUS concept is not brought to the point of commercialization, however, an R&D program could be valuable. Discussion of this innovative concept has already stimulated creative thinking on LWR safety.

Liquid Metal Reactors

It is easier to design a liquid metal cooled reactor to passively cool itself than any other kind of reactor. At least one concept has been proposed to capitalize on this inherent safety. It is in a relatively early stage of definition, but would be a small unit perhaps similar to the modular HTGR. Because of the compactness of liquid metal cores, this reactor would be even easier to fabricate in a factory and ship virtually complete.

Up to now the liquid metal reactor program has been oriented almost exclusively towards breeders. Proponents of the liquid metal reactor, however, contend that it can be competitive even if breeding is irrelevant. Major cost reductions from the Clinch River reactor would be required. If that is possible and the potential inherent safety features can be incorporated, the result could be a very attractive reactor.

Conclusion

Research and development can play a crucial role in revitalizing the nuclear option. An effective R&D effort can lead to improved reactors that may be needed by the end of the century, and can lead to improvements for existing reactors or new reactors if they are ordered. Well designed research and development activites can focus the industry's efforts on better operating methods. Finally a strong R&D program can provide tangible reassurance of Federal support, without which technological leadership will continue to drift to other countries with more active programs.

If nuclear power is to be a future option, improvements will have to be made in the management, regulation and design of the technology. These areas are all interrelated, and actions in all are necessary if public confidence is to be rebuilt. A Federal R&D program, structered to reflect the importance of these three elements and their interrelation, can go far in laying the groundwork for an acceptable nuclear future.

Mrs. LLOYD. Thank you very much, Dr. Gibbons. Any of the questions that are asked, please feel free, either one or both of you, to respond to the questioning.

I'd like to go back to point two in your summation, the productive use of a concerned public. This is something we touched on briefly this morning, that we've never had a fatality as a result of a nuclear plant incident; it's a good safety track record. But, at the same time, we've having to go back because a concerned public was never brought into the nuclear power picture or given a correct description of what was done, or what the safety features are. As a result, only the bad features of our nuclear program came to the forefront.

At the same time, even if we go to the ISR, we're still going to have the same problem of educating the public. Would you care to respond to that?

Dr. GIBBONS. Well, I agree; and it's a time in which the public does feel placed at some distance from much of what is going on in technology, whether it be nuclear power or biotechnology or space wars. It's a typical time for us to be our own Governors, as it were, and it seems to me that when one thinks of the public with respect to nuclear power, one should think not just of the citizen that lives near a reactor or has a particular concern about environmental impacts of economic activities such as making electricity, but also the public that are the bank presidents, the investors, the financial community, all the other publics that play a key role in making the ultimate decision about which way to go with power.

But I think there's no substitute for a continued attempt to keep the level of awareness high on the part of our people. I think it was Thomas Jefferson that said that an informed citizenry can be trusted with their own Government, and this is part of that example.

Mrs. LLOYD. I think we've sort of covered the nuclear industry with a cloak of secrecy that really was sort of the downfall of many of our programs, certainly contributed to many of the problems that we face today.

Mr. Crane, would you make any comments?

Mr. **Crane**. On the cloak of secrecy? Yes. Pretty clearly, the public has felt that it was misled. I don't think you can ascribe a lot of that to malevolence on the part of the industry; I think, in many cases, the industry was misleading itself about the level of safety we have had in the past and the degree of concern that should be expressed over maintaining the quality of the plants. I think, as we've established, that they can be done quite safe but many of them haven't been done well. And I think the industry has tended to be fooling itself for quite a while on what was going on there. The relation with nuclear weapons has always been a problem; people associate it in their minds with weapons and, in fact, you can get the linkage through proliferation, and that's always been a concern of the public, also. And there are a number of factors that have led up to the present state of public rejection; the last polls we had were 59 to 29 against further construction. And if those polls don't improve quite markedly, there won't be any more construction.

So almost anything that can be done to get public acceptance improved, even some things that wouldn't necessarily appear on the face of it to be in the industry's interests, might work out that way. I think that a great degree of candor is going to be required on the part of the industry to convince the public that these things can be done right; they do have problems, but it will be managed right in the future.

Mrs. **Lloyd**. Well, I will agree with you on both of your statements, but I would disagree with you on one statement, that there will be no nuclear industry, because I don't think that we can meet our energy goals when we're already looking to coal for 17 percent of our generating capacity, but there's a capacity mix that we're going to have to reach to make our energy commitments, so nuclear energy must fall into place as well.

Mr. **Crane**. It must; but if the utility is facing very strong public opposition, why should it bother? I think you will see the public opinion start to turn if, in fact, we do depend too much on coal; and if some of the more alarming scenarios come true, with the acid rain and the carbon dioxide, then nuclear power would start to look a lot better. But before we reach that state of affairs, I think there's a great deal that can be done that would improve nuclear power in the eyes of the public.

Dr. **Gibbons**. Might I add a point to that?

Mrs. **Lloyd**. Please.

Dr. **Gibbons**. It seems to me that as late evidence of successful long-term operation of powerplants begins to accumulate, there's no substitute for that kind of evidence, convincing all of us that this is an important energy source that can operate very well. The more time that goes on with a string of high performance operations such as now is gathering momentum in several utilities, I think that's going to be one of the most convincing pieces of evidence that we can rely on. So I would closely couple the imperative that's already there for trouble-free operation as a prerequisite, almost, for the reestablishment of the public confidence.

Mrs. **Lloyd**. Thank you. Your statement is well put because it is factual that the safety of plants, as Mr. Crane says, is highly questioned by over 50 percent of the people. Following also in this vein, in our DOE 1985 budget we have the following statement: "The technical approach is to utilize the inherently low power density of small HTGR's to minimize the need for engineered safety features."

Would you elaborate, for the record, what low power density involves and how this provides for an inherently safe reactor?

Mr. CRANE. I might point out for the record that I'm not a nuclear engineer. [General laughter.] However, low power density involves a core that is bigger that produces the same total power, so there's fewer fission taking place in any one unit of volume. That means that if there is an accident and you have inadequate cooling, it will take longer for the core to heat up because the heat production density is also lower. It makes it easier to start cooling coming in through again. Generally, you have a greater mass in there, particularly with HTGR, which has the graphite moderator built right in there, unlike a water reactor where the moderator can disappear with a loss of coolant. This doesn't happen with the HTGR, and just the greater thermal mass in there takes a lot longer to heat up. With the HTGR also you have the advantages that the temperature itself has to go much higher than with the LWR before it starts to get into problems, so your time frame is much, much greater before something has to happen.

Mrs. LLOYD. Thank you.

This morning, Dr. Gibbons, we heard from some witnesses that stated that the initial problem of the industry is of an economic nature, and that it is not concerned with nuclear safety. Would you agree? And turning to the HTGR they said this is a matter of economics, this is not a matter of safety, the concern of the American people.

Dr. GIBBONS. Well, I think the economics is not as certain in HTGR's simply because we've not had the experience that we've had with LWR's. I think, however, it's not a foregone conclusion that the HTGR's are more expensive than LWR's; it's that there is a greater uncertainty about what their cost will be. And the only way to solve that problem is to carry it far enough along to see what its economic advantage and disadvantage may be; but I think when they say the problem is economic, I think they're saying the problem is uncertainty about economics, not a certainty that it's going to be more expensive.

Mrs. LLOYD. Well, DOE has a perspective that the smaller reactors have advantages in today's markets and projected markets over the larger, multimegawatt sizes. Do you feel that there are advantages in costs or otherwise in fabricating and installing small reactors?

Dr. GIBBONS. If you look at the traditional costs per megawatt of a nuclear powerplant, or even of a coal-fired powerplant, you find that the cost per megawatt falls off as you make a larger and larger plant if you take into account only the cost of the plant and its size. If, however, you take into account the extra costs of field erection versus factory production, take into account other inescapable things that happen as you go to large size or small size, then this apparent economy of scale of the very large units begins to lose ground; and, in fact, the real economy of scale may be at much lower size than you would calculate just using straight first approximations. And I think that's what's beginning to be recognized, that time-to-market, quality control, advantage of the learning curve, being out of the weather, a lot of other factors that would go into a smaller unit size reactor-——

Mrs. LLOYD. Did you factor in the cost of interest?

Dr. GIBBONS. Yes, and the cost of interest comes in that you can produce over a shorter period of time if, in fact, you're making a sort of a so-called factory production; but these factors begin to pull your optimum way back down the curve toward smaller size. So that realization, now, we believe is a very important thing and should be pursued.

Mrs. LLOYD. I'd like to turn to the PIUS reactor. Do you think that the committee should fund PIUS activities such as investigating the maintenance, boronated water separation, and evaluating the technology, or research and development efforts?

Dr. GIBBONS. May I ask Alan to answer that?

Mrs. LLOYD. Please.

Mr. CRANE. The PIUS has a number of very attractive advantages, particularly in terms of safety but also possibly in operation. We think that it would be a good value to have at least a start on a program to see where it goes. It's not at all clear that the PIUS will find a role; but if it works out the way its developers think it will then, in fact, it might be very attractive and it might be deployed very quickly. Much of the technology to it is off-the-shelf hardware; it is not a totally unfamiliar concept waiting—well, I won't say totally, but the HTGR would force the utility to learn a new technology. The PIUS, it wouldn't. There are a number of things——

Mrs. LLOYD. That has been brought to the attention of the subcommittee; that is the reason I asked you the question.

Mr. CRANE. Many times. Yes, we think that the PIUS, at least in a small, initial program, could prove quite beneficial and it might turn up some things. Even if you didn't build a PIUS reactor, you might use them on light water, conventional light water technology. So it looks like it could be money very well spent; and if you find out soon that the thing isn't proving out, then you can always terminate the program later. And there are several steps along the way where you might find out that that's true.

Mrs. LLOYD. Thank you.

One final question, and this is the big question of funding. Do you think that our nuclear R&D program has a proper distribution of resources when we look at $308 million in breeder development, and then less than $50 million on all other advanced reactors?

Dr. GIBBONS. I'll take the stab at it and then ask someone that knows better than I to follow me, Alan.

It depends on—what we're talking about in that whole program is an investment in our futures and our children's futures in providing the technology substitute for cheap raw material, namely, energy. Now, I'd say one could class both those numbers as awfully small investments in the future when trying to provide a resource that is so ubiquitous to our economic and other needs. On the other hand, one can make the case that if our intermediate future, that is, over the next 10, 20, 30, maybe 50 years, lies more productively in burners rather than in breeders, then one would interpret that number as being a little strange. And I think the changed notion of the availability of uranium, the changed notion of the rates of growth of demand for electricity—all would argue that, in fact, if we choose to we can afford to postpone moving to the new kind of technology of breeding for some decades. But that doesn't say, at the same time, you can walk away from making a burner reactor work well. And I think that's the issue before us today.

Mrs. LLOYD. Any further questions the staff would like to present for Dr. Gibbons or Mr. Crane?

[No response.]

Mrs. LLOYD. If Congress directs DOE to develop an ISR program, how long do you think it would take to accomplish this goal?

Mr. CRANE. I guess it depends, in part, on what you mean by accomplishing the goal. If you are talking about commercialization where a utility could go out and buy one of these things, having firm assurance that it would be licensable and it would be operational, that's going to call for a significant demonstration of at least one, and maybe more, prototypes. Some of the concepts could be implemented sooner; for instance, the small modular HTGR, if it looks like it's going to work out economically, could probably be implemented fairly quickly just because it's small and you could build several of them and test them very quickly. I think, in a case like that, you're talking about the mid- to late-90's. The PIUS reactor, if it could lean on the present technology and if it works fairly quickly, that might be something like a 10-year program. We will have better numbers on these schedules as we complete the write-up of the workshop that we did; we are now working on some schedules.

Mrs. LLOYD. Mr. Crane, are you talking about one or more prototypes?

Mr. CRANE. I think with the PIUS, if it works, probably one prototype would be adequate.

Mrs. LLOYD. But on the HTGR?

Mr. CRANE. On the HTGR it's awfully hard to say on the big one. On the little one, it really doesn't matter if you run several prototypes because they're small and easily built and the total capacity might be less than one big one, and so that's why I think you could prove that one out fairly quickly if it works. With the big one, it's just awfully hard to say; if you have a lot of problems with the first one, most utilities would find it prudent to tell you to go back and build another one first.

Mrs. LLOYD. Thank you.

I think that Dr. Dugan has a question also that he would like to present.

Dr. DUGAN. Thank you, Madam Chairman.

Dr. Gibbons, the previous OTA report, Nuclear Power Plant Standardization, had some findings about potential safety benefits that were desirable for standardization but said, however, the extreme single design approach to standardization could pose so many institutional difficulties and generic risks the problems would outweigh the benefits. In light of the most recent report, has there been an OTA reassessment of that view, or was it looking at standardization in a different context?

Dr. **Gibbons**. I think some of our concern, much of our concern, about standardization still obtains; namely, if you standardize by freezing design, then you can argue that you've frozen the technology along with the standardization. However, if you look in—and I may forewarn Alan Crane that he ought to add to my response—but if you look in other sectors of our economy, we have gotten to a lot of standardized things in industries that are annually changing their designs, upgrading them; and yet, they operate in a more or less standardized mode. I think of automobiles or of gas turbines or of airplanes. There are many things that are standardized and have led to very high productivity, cost reduction, monetary savings. So I don't feel that the word standardization can be defensively translated to technology freezing; but it is a concern we have and, obviously, if one moves toward standardization as the French are doing, one has to keep that in mind.

Dr. **Dugan**. Was the certification approach an option considered in the standardization report?

Mr. **Crane**. Yes, it was. We talked to GE quite a bit on their powerworthiness certification and, in fact, they now have their final design approvals. So if, in fact, the NRC does not go back for a design review, they really have a standardized plant already that extends to a good bit of the balance of plant. Combustion Engineering also, in the last few weeks, was granted an FDA and Westinghouse would be looking for that on their advanced PWR. So I think we are seeing a considerable increase in standardization and, in fact, I think we took it for granted in this study that that was a prerequisite for any utility to be willing to go ahead with another one, that it would have virtually complete approval before it started construction. And the only way you can achieve that is through standardization.

Mrs. **Lloyd**. Thank you very much, Dr. Gibbons and Alan Crane; thank you for your very fine work on "Nuclear Power in an Age of Uncertainty." And for those of you here that would like to have a copy, they are for sale. Thank you very much.

Dr. **Gibbons**. Thank you, Madam Chairman.

Mrs. **Lloyd**. Dr. Behrens is from the Congressional Research Service of the Library of Congress; we welcome you to our hearings today and look forward to your testimony. You may proceed as you wish; your entire statement will be made a part of the record and you may summarize as you wish.

STATEMENT OF DR. CARL E. BEHRENS, SPECIALIST IN ENERGY POLICY, CONGRESSIONAL RESEARCH SERVICE

Dr. **Behrens**. Thank you, Madam Chairman.

I would like to describe today the results of a CRS study which aimed at investigating the potential market for smaller sized nuclear plants. I will take advantage of your offer and submit the full report that I've prepared.

Mrs. **Lloyd**. Without objection, it will be made a part of the record.

Dr. **Behrens**. Thank you.

Our approach to this question was shaped by the following facts. First, the typical nuclear powerplant under construction at present is very large in terms of generating capacity. The average is more than 1,000 megawatts, and none is less than 800 megawatts. This uniformity of size is not characteristic of coal-fired plants. The average capacity of coal plants scheduled to come on line in the 1980's is 500 megawatts, but the units vary all the way from less than 100 megawatts to more than 1,300.

The second point is that the economies of scale for the current designs of nuclear plants are probably very high—that is, the capital cost of a small-sized plant may be as much as 30 to 50 percent greater per kilowatt of capacity than the cost of a large plant.

The third point is that utilities are having great difficulty in completing construction of nuclear units that are already underway. The slow growth in demand for power since the early 1970's has eroded the need for new capacity, and high interest rates have been a major contributor to steep increases in the cost of these construction projects. Numerous utilities have had to cancel plants in which they have invested hundreds of millions of dollars.

The current financing difficulty involved in building large plants has stimulated interest in designs of smaller units. One aim of this research is to design a plant that would cost less per kilowatt than mere scaled-down versions of present design. These efforts give rise to two questions.

One, if there were a smaller nuclear unit—on the order of 400 megawatts—which was only 10 to 20 percent more expensive per kilowatt than a large one, would it be easier to finance?

The second question, what would the cost of producing power for a typical utility be if it met growth in demand with such 400-megawatt units, compared with the cost if it built typically larger nuclear units?

These questions must be answered in terms of the utility's whole financial and operational environment. To do that, we contracted to use a model that was developed at the Rensselaer Polytechnic Institute to measure the cost of producing power, and other significant measures, for a utility with specified financial and operational parameters. We had two reference cases. In one, it was assumed that the utility would build 400-megawatt nuclear units as necessary to meet its growth in load; in the second, that it would meet its load growth by building 1,200-megawatt units. The smaller plants were assumed to cost 12 percent more per kilowatt than the larger units.

In addition to the reference cases, the sensitivity of the results to changes in various parameters was modeled. The parameters we tested included interest rates, the fuel mix of the utility, the cost differential between the 400-megawatt and the 1,200-megawatt plants, and the rate of growth of load.

It should be emphasized that the study compared costs and other financial measures for small and large nuclear plants only. It did not compare nuclear with coal, or conservation, or other fuels and technologies; nor did it address aspects of nuclear power which are subject to controversy at present, and which affect the economics of nuclear power in general.

Mrs. LLOYD. Excuse me, Dr. Behrens. Did you factor in the cost of interest?

Dr. BEHRENS. Yes, indeed. The interest cost was a central factor, a central parameter in this case.

Mrs. LLOYD. Thank you.

Dr. BEHRENS. With these restrictions, the results of the modelling performed for this study indicate strongly that small nuclear powerplants could have a market under the right conditions. Not only was the difference in the cost of producing power for the small and large cases relatively small, but the financing of the smaller units was considerably easier in each of the cases that we ran.

We measured financing ease by the utility's coverage ratio, and that's the amount of net revenue that the utility takes in each year divided by the interest that it has to pay out. The coverage ratio is largely a measure used by utility commissions in their deliberations over rates; but it is also an indicator of the utility's financial health at that time. If a utility's coverage ratio falls too low, then it can have a powerful, although unquantifiable, effect on the utility's bond rating, and thus on the amount of interest that the utility must pay on new issues.

In each case the building of large nuclear units caused the coverage ratio to fall lower than it did when demand was met by building small units. In many of the large plant cases it fell below 2.0, the level at which some utilities are prohibited from raising new debt. In contrast, the coverage ratio did not fall below 2.0 in any small unit case, and in most cases it stayed above 3.0. It is impossible to turn a measure of the coverage ratio into a cost-of-production figure, but there is no doubt that, in times of uncertain growth and high interest rates, and we've been hearing about that today, the coverage ratio and the financial situation it reflects will have an important effect on the utility's cost of money, and even its ability to raise cash at all.

The cost figures we computed were equally encouraging. In all cases, the cost of producing power for the whole system, assuming new load was met by building the small plants, differed only in tenths of a mill from the cost when large units were built.

If a utility, then, can meet its load requirements by constructing 400-megawatt plants to come on line spaced 4 or 5 years apart, then the higher capital cost which we assumed that the small plant would have is strongly compensated for by the more level financing requirements and the lack of periodic overcapacity that typifies large plant construction. If interest rates are very high—and, Madam Chairman, this is a very important point—if interests are very high, in fact, the cost penalty is entirely overcome.

At higher growth rates, and for very large utility systems, the cost advantage of small units measured by this model in this study largely disappears. Under those circumstances, a utility would have to add a smaller plant every year or so, and the financing advantage of the small units is lost to a certain extent. Nevertheless, the coverage ratio and the financial condition it reflects remained consistently better for the small units than for the large units.

Keeping in mind the study's limitations, the main conclusion of the modelling exercise carried out in this study is that the economies of scale of large plants tend to be overcome—at low demand growth rates and high interest rates—by financing difficulties. These difficulties are avoided if small units are built. Thus, if a small nuclear plant existed, it would probably find a good market, assuming continued low or modest growth rates and continuing high cost of money. It would not be in that market alone, however; competing in it would be other fuels and technologies, as well as the options of joint ownership of large plants, and purchasing of power from other utilities. The choice between these options would be very much dependent upon the individual utility's situation and projections of future demand and conditions.

This concludes my formal statement. I would be glad to answer questions about the study and its conclusions.

[The prepared statement and study of Dr. Behrens follows:]

Congressional Research Service
The Library of Congress

Washington, D.C. 20540

STATEMENT BY CARL E. BEHRENS, SPECIALIST IN ENERGY POLICY
CONGRESSIONAL RESEARCH SERVICE
AT A HEARING BEFORE THE SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY
FEBRUARY 7, 1984

I would like to describe the results of a CRS study which aimed at investigating the potential market for smaller sized nuclear plants. With your permission, I will submit the full report for the record.

Our approach to this question was shaped by the following facts:

1. The typical nuclear powerplant under construction at present is very large in terms of generating capacity. The average is more than 1,000 megawatts, and none is less than 800 megawatts. This uniformity of size is not characteristic of coal-fired powerplants. The average capacity of coal plants scheduled to come on line in the 1980's is 500 megawatts, but the units vary all the way from less than 100 megawatts to more than 1,300.

2. The economies of scale for the current designs of nuclear plants are probably very high--that is, the capital cost of a small-sized plant may be as much as 30 to 50 percent greater per kilowatt of capacity than the cost of a large plant.

3. Utilities are having great difficulty in completing construction of nuclear units that are already underway. The slow growth in demand for power since the early 1970's has eroded the need for new capacity, and high interest

rates have been a major contributor to steep increases in the cost of these construction projects. Numerous utilities have had to cancel plants in which they have invested hundreds of millions of dollars.

The current financing difficulty involved in building large plants has stimulated interest in designs of smaller units. One aim of this research is to design a plant that would cost less per kilowatt than mere scaled-down versions of present design. These efforts give rise to two questions:

1. If there were a smaller nuclear unit--on the order of 400 megawatts--which was only 10 to 20 percent more expensive per kilowatt than a large one, would it be easier to finance?

2. What would the cost of producing power for a typical utility be if it met growth in demand with such 400-megawatt units, compared with the cost if it built typically large nuclear units?

These questions must be answered in terms of the utility's whole financial and operational environment. To do so, we contracted to use a model developed at Rensselaer Polytechnic Institute to measure the cost of producing power, and other significant measures, for a utility with specified financial and production parameters. Two reference cases were considered: in one, it was assumed that the utility would build 400-megawatt nuclear units as necessary to meet its growth in load; in the second, that it would meet its load growth by building 1200-MW units. The smaller plants were assumed to cost 12 percent more per kilowatt than the larger units.

In addition to the reference cases, the sensitivity of the results to changes in various parameters was modelled. The parameters tested included interest rates, fuel mix, cost differential between the 400-megawatt and 1,200-megawatt plants, and the rate of growth in load.

It should be emphasized that the study compared costs and other financial measures for small and large nuclear plants only. It did not compare nuclear with coal, or conservation, or other fuels and technologies. Nor did it address aspects of nuclear power which are subject to controversy at present, and which affect the economics of nuclear power in general, such as safety, radioactive wastes, or nuclear proliferation.

With these restrictions, the results of the modelling performed for this study indicate strongly that small nuclear powerplants could have a market under the right conditions. Not only was the difference in the cost of producing power for the large and small cases relatively small, but the financing of the smaller units was considerably easier in each of the cases run.

Financing ease was measured by the utility's coverage ratio: the amount of net revenue the utility takes in each year divided by the interest it must pay out. The coverage ratio is largely a measure used by utility commissions in their deliberations over rates and construction plans, but it is also an indicator of the utility's financial health at the time. If a utility's coverage ratio falls too low, it can have a powerful, though unquantifiable, effect on the utility's bond rating, and thus on the amount of interest the utility must pay on new issues.

In each case the building of large nuclear units caused the coverage ratio to fall lower than it did when demand was met by building small plants. In many of the large-plant cases it fell below 2.0, the level at which some utilities are prohibited from raising new debt. In contrast, the coverage ratio did not fall below 2.0 in any small-unit case, and in most cases it stayed above 3.0. It is impossible to turn a measure of the coverage ratio into a cost-of-production figure. But there is no doubt that, in times of uncertain growth and high interest rates, the coverage ratio and the financial situation it reflects will have an important effect on the utility's cost of money, and even its ability to raise cash at all.

The cost figures were equally encouraging. In all cases, the cost of producing power for the whole system, assuming new load was met by building the small plants, differed only in tenths of a mill from the cost when large units were built. While cost differences of this magnitude can build up to sizeable amounts on an entire system, they are much less than the differences caused by other factors such as interest rates or fuel mix.

If a utility can meet its load requirements by constructing 400-megawatt plants to come on line spaced 4 or 5 years apart, then the higher capital cost of the small plant is strongly compensated for by the more level financing requirements and lack of periodic overcapacity that typifies large plant construction. If interest rates are very high, in fact, the cost penalty is entirely overcome.

At higher growth rates, or for very large utility systems, the cost advantage of small units measured by the model in this study largely disappears. Under those circumstances, a utility would have to add a smaller plant every year or so, and the financing advantages of the small units is lost. Nevertheless, the coverage ratio, and the financial condition it reflects, remained consistently better for the small units than for the larger ones.

Keeping in mind the study's limitations, the main conclusion of the modelling exercise carried out in this study is that the economies of scale of large plants tend to be overcome, at low demand growth rates and high interest rates, by financing difficulties. These difficulties are avoided if small units are built. Thus, if a small nuclear plant existed, it would probably find a good market, assuming continued low or modest growth rates and continuing high cost of money. It would not be in that market alone, however. Competing in it would be other fuels and technologies, as well as the options of joint ownership of large plants, and purchasing power from other utilities. The choice between these options would be very much dependent upon the individual utility's situation and projections of future demand and conditions.

This concludes my formal statement. I would be glad to answer questions about the study and its conclusions.

ECONOMIC POTENTIAL OF SMALLER-SIZED NUCLEAR PLANTS IN TODAY'S ECONOMY

PREFACE

The calculations and computer modelling reported in this study were performed at the Rensselaer Polytechnic Instutute under contract with the Congressional Research Service. The RPI contract was directed by Dr. Martin Becker and Dr. Frank Wicks, with the assistance of Rong-Fuh Louh. Major design support and analysis for this study were provided by Alvin Kaufman, Senior Specialist in Mineral and Regulatory Economics. Also contributing comments and suggestions were Dr. Warren H. Donnelly, Dr. Robert Civiak and Dr. Larry B. Parker of CRS, and Dr. Alan Crane of the Office of Technology Assessment.

ECONOMIC POTENTIAL OF SMALLER-SIZED NUCLEAR PLANTS IN TODAY'S ECONOMY

EXECUTIVE SUMMARY

Financial difficulties and low load growth since the 1973 Arab oil embargo have halted the ordering of new nuclear powerplants, and have led to delays and cancellation of many plants already ordered and under construction. Contributing to the difficulties experienced by utilities in constructing nuclear plants has been the large size of the units—typically larger than 1,000 megawatts electric.

Plants this large made sense when demand for electricity was growing rapidly, as it was when most of them were ordered; under such conditions the economies of scale that result from larger units can be realized, with a resulting lower costs of power production. But in times of slow growth the large investment in a single project can be both expensive and risky, especially when interest rates are high. In such circumstances the greater flexibility and lower up-front investment requirements of smaller units can compensate for a higher capital cost per kilowatt of capacity.

Measuring the effect of these various factors must be done in terms of the utility's whole financial and operational environment. In this study, the cost of producing power was modelled for a utility with specified financial and production parameters. Two reference cases were considered: in one, it was assumed that the utility would build 400-megawatt nuclear units as necessary to meet its growth in load; in the second, that it would meet its load growth by building 1200-MW units. The smaller plants were assumed to cost 12 percent more per kilowatt than the larger units. The object was to see if the lower financing costs of the 400-megawatt units were enough to overcome the larger plants' economies of scale.

In addition to the reference cases, the sensitivity of the cost measurement to changes in various parameters was modelled. The parameters tested included interest rates, fuel mix, cost differential between the 400-megawatt and 1,200-megawatt plants, and the rate of growth in load.

The results of these cases indicate strongly that small nuclear power plants could have a market. In all cases, the cost of producing power for the whole system, assuming new load was met by building the small plants, differed only in tenths of a mill from the cost when large units were built. While cost differences of this magnitude can build up to sizeable amounts on an entire system—for a 7,000-megawatt utility they would be on the order of $20 million per year--they are much less than the differences caused by other factors such as interest rates or fuel mix.

If a utility can meet its load requirements by constructing 400-megawatt plants to come on line spaced 4 or 5 years apart—for the 7,000-megawatt utility modelled in this study, that means a growth in load of less than 1 percent per year—then the higher capital cost of the small plant, not very significant in total cost calculations in any case, is strongly compensated for by the more level financing reqirements and lack of periodic overcapacity that typifies large plant construction. If interest rates are very high, in fact, the cost penalty is entirely overcome.

The existing fuel mix of the utility was also found to be a significant factor. In the reference cases, the utility's capacity was assumed to be more than 50 percent oil-fired. This gives an advantage to the large-plant case, since the excess nuclear capacity can be used to back out expensive oil. When it was assumed that the existing oil-fired capacity was changed to coal, system costs were virtually identical in the 400-MW and 1,200-MW cases, despite the assumed 12 percent capital cost differential.

Another aspect of utility economics is the "coverage ratio": the amount of revenue the utility takes in each year divided by the interest it must pay out. The coverage ratio is largely a measure used by utility commissions in their deliberations over rates and construction plans, but it is also an indicator of the utility's financial health at the time. As such it can have a powerful, though unquantifiable, effect on the utility's bond rating, and thus on the amount of interest the utility must pay on new issues.

In each case the building of large nuclear units caused the coverage ratio to fall lower than it did when demand was met by building small plants. In many of the large-plant cases it fell below 2.0, the level at which some utilities are prohibited from raising new debt. In contrast, the coverage ratio did not fall below 2.0 in any small-unit case, and in most cases it stayed above 3.0. It is impossible to turn a measure of the coverage ratio into a cost-of-production figure. But there is no doubt that, in times of uncertain growth and high interest rates, the coverage ratio and the financial situation it reflects will have an important effect on the utility's cost of money, and even its ability to raise cash at all.

At higher growth rates, or for very large utility systems, the advantage of small units measured by the model in this study largely disappears. Under those circumstances, a utility would have to add a smaller plant every year or so, and the financing advantages of the small units is lost. Nevertheless, the coverage ratio, and the financial condition it reflects, remained consistently better for the small units than for the larger ones.

A number of assumptions were necessary in modelling the utility's financial behavior which might affect the outcome in a real-life situation, and thus may call into question the conclusion drawn from the model.

Most important is the assumption that a 400-megawatt design exists which would cost no more than 12 percent per kilowatt than a 1,200-megawatt plant. No 400-megawatt plant is currently licensable in the U.S., and the economies of scale of existing light-water reactors are probably much greater than 12 or even 24 percent. Several designs have been explored, however, which promise capital cost differentials that are in the range used in this study.

One option not discussed at length in this study is joint ownership of a large plant. This technique would have the same financing advantages as building a small plant, and would preserve the economies of scale of the large unit. Joint projects involve uncertainties and difficulties in matching the needs and capabilities of the partners, however. Another option not discussed purchase of needed power from other utilities. This practice is widespread, particular in times of considerable excess capacity like the present. It has obvious advantages and disadvantages.

Two assumptions were made that give a possible advantage to the large plants: it was assumed that both small and large units would operate at a capacity factor of 65 percent, and that it would take 8 years to build a unit of either type. There is much controversy over whether large units are less reliable than smaller ones, but the available data are too sketchy to make it practical to measure the effect of this factor, especially since it was necessary to assume a small-plant design on which there is no operating experience at all. Similarly, the data on construction times are so distorted by the load-growth variations of the past decade that rational judgments on actual time necessary for construction seemed impractical.

Finally, it is impossible to measure the uncertainty arising from variations in interest and inflation rates, load growth rates, and construction and licensing delays. A few points in the interest paid on a bond issue in a crucial construction year, for instance, or the curtailment of cash flow caused by economic or weather-related factors, can make a major difference in cost of construction; they may even make the difference between continuing the project or cancelling it. The assumption of unchanging interest and inflation rates, and of steady growth in load, clearly favors the large plants, giving them an advantage that they do not possess in the real world.

The main conclusion of the modelling exercise carried out in this study is that the economies of scale of large plants tend to be overcome by financing difficulties which are avoided if small units are built. A number of simplifying assumptions were necessary to run the model, but except for the primary assumption that a small plant design exists, all these assumptions favor the large plant. Making them, therefore, does not weaken the conclusion: that if a small nuclear plant existed, it would probably find a good market. It would not be in that market alone, however. Competing in it would be other fuels and technologies, as well as the options of joint ownership of large plants, and purchased power.

ECONOMIC POTENTIAL OF SMALLER-SIZED NUCLEAR PLANTS IN TODAY'S ECONOMY*

INTRODUCTION

The poor state of the nuclear option is well known. No new plants have been ordered since 1978, and nearly 70 existing orders have been cancelled--including a number in which hundreds of millions of dollars had been invested. Virtually every surviving project has been deferred from one to a dozen or more years. The probability of renewed interest in constructing nuclear plants, beyond those already underway, seems small at present.

Opposition to nuclear power, strongly enhanced by the accident at Three Mile Island, has no doubt contributed to utility disenchantment with the nuclear option. The major influence, however, has been financial. The drop in growth of demand for electric power since the embargo, combined with the very high interest rates and the expectation of inflation and cost overruns, have made hash of utility construction plans formulated and begun in the late 1960s and early 1970s. Projects begun in that period, on the expectation that they would be needed within a few years, became financial albatrosses--difficult to justify, impossible to fund. Even when completed, these large projects have brought financial problems: huge investments on the books for years earning no return, suddenly brought into the rate base with a devastating effect either on consumer rates or on utility return on investment.

REACTOR SIZE

One feature of nuclear power plants that is most notable to the public and the policy maker is the large size of each unit---not physical size, since except for the peripheral cooling towers nuclear generators are relatively small, but the large amount of power each unit can produce. While the first commercial plants in the early 1960's were in the 300-600 megawatt range--about the same size as most large coal units being built--the designers quickly scaled up the unit size to 1,200 and 1,400 megawatts.

---

*By Carl E. Behrens, Specialist in Energy Policy, Environment and Natural Resources Policy Division

There were two basic reasons for this increase. Unit size in fossil plants had been increasing also, resulting in lower production costs because of economies of scale. Nuclear technology was even more sensitive to such economies of scale than fossil generation. More important, demand for electricity was growing so rapidly that even very large units were expected to be fully utilized as soon as they could be brought on line; in fact, it was growing so fast that utilities were ordering large plants in batches of two, three, and even four units, scheduling them to come on line in intervals of a year or two.

It is worth discussing these two points at greater length.

Economies of Scale. Several factors contributed to the decline in costs of producing power up to the late 1960's. Higher combustion efficiencies and declining real price of fuel were two. A third major factor was a trend toward larger units, which were able to produce perhaps twice as much power from a plant that cost only half again as much to build. 1/

1/ This relationship can be expressed by ratios:

$$(\text{Cost of Unit A})/(\text{Cost of Unit B}) = [(\text{KW Rating of Unit A}/\text{KW Rating of Unit B})]^{P}$$

If Unit A costs 50 percent more than Unit B, and if it has two times the kilowatt rating, then:

$$1.5 = (2)^{P} \quad ; \quad P = 0.6 \text{ (approximately)}$$

This formulation came to be called the "Six-Tenths Power Law". See Comtois, W.H. "Economy of scale in power plants." Power Engineering, August 1977, pp. 51-53. Already by 1977, Comtois was challenging the validity of the Six-Tenths Power Law, arguing that it should be lower.

The economies of scale observed in fossil-fueled plants seem likely to be both more important and greater for nuclear plants: more important because nuclear capital costs are a greater proportion of total power production costs, and greater because the inherent design features of nuclear plants, such as the single large pressure vessel, and the cost of special safety features and equipment, are not much affected by the power output of the plant.

These theoretical considerations were a major factor in the rapid scaling-up in nuclear powerplant size in the late 1960's and early 1970's. But even as they were being put into practice, the conditions that might have made them valid were changing.

Interest Rates and Inflation. There is a general impression that the economic roof fell in on the electric utility industry following the Arab oil embargo in 1973 and 1974, and to some extent that is true. Certainly the fall-off in power sales that resulted from that event had a revolutionary effect on the industry. But in one respect the troubles of the post-embargo period actually began earlier--seven years earlier, to be exact. That was when interest rates began to rise rapidly.

From the mid-1930's to the mid-1950's yields on light, power and gas bonds never rose above 4 percent per year. During the next decade those rates hovered between 4 and 5 percent. But in 1966 yields began a 5-year rise that took them to almost 9 percent—twice the rate in 1965. A brief dip in 1971 and 1972 was followed by a sharp jump to 10 percent; another two-year improvement was quickly wiped out as the cost of raising money in the bond market soared above 16 percent per year in 1981. 2/

2/ Source: Moody's Weighted Averages of Yields on Newly Issued Domestic Bonds and Preferred Stocks. Other interest rates followed a similar pattern.

Inflation followed a similar path, without the dips. The index of public utility construction costs rose from the mid-100's in the 1960's (with 1949 construction costs set at 100) to reach 200 in 1970, 300 in 1974, 400 in 1977 and 500 in 1980. 3/

The significance of these factors for economies of scale is not immediately obvious. At first glance it would appear that higher interest rates would actually enhance the cost advantage of the larger unit; that they would add "leverage" to the cost differential between the small and large units. But inflation and interest of the sort that prevailed in the 1970's wiped out that leverage by reducing demand.

The inflation was accompanied by, and was largely the source of, a sharp decline in the growth in demand for electric power. The effect of lower growth was that increases in demand no longer required the addition of thousands of megawatts every few years; they could be met by adding smaller units every three or four years. Large units, on the other hand, could only be utilized fully over a period of ten or twelve years. The steadier, less cyclical program involving staggered completion of small units reduces the financial exposure of the utility and therefore the total amount of interest it must pay to obtain the same amount of generating capacity.

A numerical illustration may help. Assume that a utility can meet future demand in one of two ways: either by building a single 1,200-megawatt unit to come on line by 1990, or by building three 400-megawatt units to come on line in 1990, 1994, and 1998. (This example foreshadows the cases that were modelled in the computer runs to be described later.) Assume

---

3/ Source: EEI Statistical Yearbook 1981. Table 85. Cost Trends of Electric Light and Power Construction.

further that it takes eight years to build either a 1,200-MW unit or a 400-MW unit.

In both cases, the utility will have to start investing money in 1982 for the plant due in 1990. But in the case of the large plant, the cost of the entire 1,200 megawatts must be financed by 1990, and the utility must be paying interest on that amount of investment. In the small-unit case, on the other hand, the financing is stretched out. The second 400-MW unit does not need to be started until 1986, and the third not until 1990. As a result, in the 400-MW case the utility must pay interest for eight years less on a third of the investment, and four years less on another third, than it does in the 1,200-MW case. Those extra years of interest payments must be subtracted from the economies of scale that the large plant enjoys. If the interest rate is high enough, it may overcome the large plant's cost advantage entirely.

Of course, if interest and inflation are high enough, and electricity sales low enough, then the utility becomes unable to fund any construction at all—even if it might be economically justifiable in the longer run. Financing difficulties have been a major factor in many plant deferrals and cancellations. Here again, the large plant project is at a disadvantage, since a larger amount of financing must be squeezed into the eight-year construction period, instead of being spread over 16 years as in the small-plant case.

Load Growth and Plant Size. The main facts about the electric utility industry today can be capsulized in two short sentences:

1. From 1960 to 1972 electric power production increased at an average annual rate of 7 percent.

2. From 1973 to 1981 production increased at an average annual rate of 2 percent.

As a footnote to the second sentence, it might be noted that in 1982 production actually declined, for the first time since the 1930's, 2.2 percent below the 1981 figure—mostly the result of economic recession and mild weather.

To illustrate the effect of such a transition from high growth to low growth on a utility's construction program, an example is helpful once again. For a utility with a peak of 3,000 megawatts, 7 percent annual growth means an increase of 40 percent in 5 years. If the new capacity runs 60 percent of the time, that means a market for the output of 2,000 megawatts of generating capacity: two 1,000-megawatt units in the space of 5 years. Obviously, at the end of that 5-year period, an even greater increase in capacity will be required to meet a continued 7-percent growth.

The arithmetic in this example goes a long way to explain why the assumed economies of scale for large nuclear units were not sharply examined by utilities ordering them. To a company with a perceived need to add 2,000 megawatts of generating capacity in 5 years, and perhaps 3,000 to 4,000 megawatts in the following half-decade, the tendency would be to look for the largest units available--as long as the estimated cost per kilowatt was not significantly greater for the larger unit. If it was estimated to be smaller, so much the better. Utilities in the late 1960's and early 1970's were not only ordering large units, but were ordering them in groups of two, three and even four at a time.

The drop in load growth since the first oil crisis changed these calculations drastically. But the trend was not immediately obvious. In 1974, power production for all utilities, public and private, was essentially flat; for investor-owned utilities, it actually declined. But there was a modest increase in production in 1975, and a vigorous spurt in 1976. To many, it appeared that the economy had absorbed the terrible shock of the quadrupling of oil prices, and was ready to move forward as it had in the past. It was also believed that electric power, produced by sources other than oil or gas, would be competitive in many uses where it had earlier been too expensive. By 1976 virtually all capacity under construction was to be fueled by coal or uranium. That appeared to put the utility industry in a position to take advantage of the changed energy economics.

It has been said that projecting the future is like driving a car while looking in the rear-view mirror. 4/ One can tell if the road is generally straight or curved, but one can only guess which way it will turn.

In the 1970's, the growth road for the utilities suddenly left the broad plains of steady growth and abruptly climbed into the mountains. A natural reaction was to move more cautiously. But there was no way of being sure that growth would resume again. Or that it would not.

In fact, it didn't. In 1979 and 1980 the Iran crisis led to another mad runup of oil prices. That was followed in 1981 and 1982 by a deep recession. By that time the industry was practically unanimous: slow growth was here to stay.

The dampening of growth combined with galloping inflation and interest rates to make a shambles of the construction programs of most of the utilities in the country. The 40-percent increase that had been expected within

---

4/ Parker, Larry. The U.S. energy outlook: 1980-2000. in U.S. Congress. House. Committee on Energy and Commerce. U.S. energy outlook: a demand perspective for the eighties. (Committee Print 97-Q). 97th Congress. 1st Session. July 1981. pp. 87-88.

5 years—at a 7-percent annual growth rate—now would not occur for 17 years, if the current 2-percent growth rate continued that long. Even if a utility thought growth would increase again, or thought a coal or nuclear unit could pay for itself by replacing oil generating capacity, it was frequently unable to continue with a construction project. Not only were State utility commissions slow to grant rate increases, but when they did, customers reacted by cutting back use. Just at the time that costs of construction were going up, revenues that could be used for construction were going down. Such revenues that did increase were driven by the cost of oil; and they came in and went out again without having more effect than driving more customers to conserve and cut back on power consumption.

So the reaction was to cut back alike in construction. A first glance at the trend in utility construction expenditures over the 1970's period seems to contradict this observation: expenditures for production facilities went from $1.3 billion in 1960 and $4.0 billion in 1969 to $17.8 billion in 1980. But this increase took place in the context of the inflation. If the expenditures are deflated according to the cost-of-construction index (see page 4) then the picture changes. Expenditures increased rapidly up to 1974, matching the rapid growth in load, which was climbing faster than capacity was increasing. When load growth leveled off, so did expenditures—very abruptly. In terms of deflated dollars, construction expenditures have been essentially flat since 1974. 5/

Construction was cut back in a number of ways. Projects that were just starting, or not yet started, were cancelled or deferred indefinitely. Construction of plants well underway was sometimes stretched out a number of

---

5/ Source: EEI Statistical Yearbook 1981. Table 69. Construction Expenditures--Investor-Owned Electric Utilities.

years. Where construction was continued, some critics argued that utilities were building useless capacity in order to be able to include the investment in the rate base, so as to increase profits.

In such an environment, utilities were not about to order new nuclear plants. The last plant ordered was Commonwealth Edison's Carroll County station in 1978, and even that order is on indefinite hold. In fact, the last-ordered project still being actively pursued is Public Service of Indiana's Marble Hill station, which was ordered in 1974; and the viability of that project is currently in some doubt.

Since the 1979 TMI accident, there has been little action even on plants that had been ordered but had not yet received NRC construction permits. The new safety requirements imposed by NRC made demands on projects that were already operating as well as those that were under construction. Neither NRC nor utility applicants had much energy or interest in pursuing new plants. The last construction permit issued was, once again, for the Marble Hill project, in April 1978.

Why Not Smaller Units?

The foregoing historical review goes far to explain why utilities did not move more flexibly to adopt the idea of small units. A summary of these points may be useful.

1. Prior to early 1979, it was by no means obvious that load growth would remain slow for an extended period. It is only at slow growth rates that smaller units can overcome their initial higher cost by spreading the investment over a significantly greater number of years.

2. Licensing of nuclear plant construction is an expensive and lengthy undertaking, not conducive to flexibility in the face of changing conditions.

This has been particularly true since the TMI accident: the period in which small units began to appear economically more attractive.

As a result of these factors, utilities with nuclear units under construction or on order were essentially locked into the designs they had ordered. There were only two options: either continue construction of the plant as licensed, or defer or cancel the project. The option to build a smaller nuclear unit did not seem to exist. 6/

This inflexibility regarding size in nuclear units contrasts with the very great variability in the size of coal-fired powerplants. Coal plants scheduled to come on line in the 1980's average 500 megawatts, but the units vary all the way from less that 100 megawatts to more than 1,300. Obviously, economy of scale in coal plants is not an important enough factor to force all utilities to build the largest technologically feasible unit. Nuclear units for the same period, on the other hand, average more than 1,000 megawatts, and virtually none of them is less than 800 megawatts. 7/

6/ Some utilities chose to switch from nuclear units to smaller coal-fired plants. Central Maine Power ordered an 1,150-megawatt nuclear plant, Sears Island, in 1974, aiming at commercial operation in 1983. In 1977 it cancelled the nuclear unit and substituted a 568-megawatt coal-fired plant, to begin operation in late 1986. The coal project is still on the books, with a start-up date of late 1989. A similar switch from nuclear to coal was announced by Virginia Electric Power, which cancelled Surry 3 and 4, twin 860-megawatt units, in 1977. VEPCO blamed the regulatory system for making it impossible to build a nuclear power plant, and said it would meet future load growth with coal, but it did not announce any new coal plants at the time and currently has no coal-fired units under construction. VEPCO has converted some of its oil-fired plants to burn coal.

7/ National Coal Association. Steam electric plant factors: 1980. Washington: NCA, 1982. Derived from Table 12 and Table 13, pp. 136-143.

THE SMALL NUCLEAR UNIT: IS THERE A MARKET?

The smallest U.S. nuclear plant commercially available at present 8/ is a 600-megawatt version of the Westinghouse standard plant. Even if there were a smaller design for sale, clearly no market exists for it—not when utilities across the country are deferring and cancelling both coal and nuclear plants, some of which involve large amounts of capital already invested.

There is nevertheless considerable interest, mostly theoretical at present, in designing a smaller unit that would capitalize on the advantages that such a plant would have, and minimize the cost penalties inherent in giving up whatever economies of scale exist for larger units. The first major thrust in this direction came from Babcock and Wilcox, which in 1978 gathered wide attention by proposing to adapt the reactor it had designed for merchant marine use to a 400-mwe land-based power generator. B&W lost much of its interest in future commercial nuclear markets following the accident at its TMI reactor, but the Department of Energy continued to work on the concept and has developed it to a fairly detailed level, to the point where it estimates that the cost penalty will be in the range of 12 percent or less--much smaller than the economies of scale of the standard light-water reactors such as the Westinghouse design. Another line of development has been pursued by the Swedish firm Asea-Atom, aimed at a reactor concept that would be inherently safer than the present designs. The increased safety of the new design, according to the Swedish concept, would eliminate the need

---

8/ The definition of commercial availability in an industry which had its last sale five years ago is a little hazy. Westinghouse has a standard plant that comes in three sizes: 600, 900, and 1,200 megawatts. However, it has sold mostly the 1,200-mw version, with a few 900-mw units. The last Westinghouse plants in the 600-mw range were the two-unit Prairie Island station in Minnesota, which were sold in 1967 and came on line in 1973 and 1974.

for some of the safety systems now required on present plants, compensating in cost for the lost economies of scale inherent in the smaller plant. The West German firm, KWU, has advertised its interest in supplying small plants, and Japan's Technology Ministry has shown some interest---although Japan's major effort in new design is a project with Westinghouse, Mitsubishi and five Japanese utilities for a 1,200-1,400-MW Light Water Reactor with more efficient fuel utilization and a longer refueling cycle. 9/ The smallest plant available on the world market is the Soviet Union's 440-MW standard export design.

If designs for low-cost small plants were developed to the commercial level, would there be a market for them? It was to help answer this question that CRS addressed its efforts, in conjunction with the Rensselaer Polytechnic Institute, to model the cost of building both small and large nuclear units. Because the cost advantages of each type of unit depend on the utility's financial and sales situation, the model was designed to measure the cost of power in the utility environment, with certain key parameters being varied to see how they affected the outcome.

THE RPI MODEL

The model developed by the Department of Nuclear Engineering at Rensselaer Polytechnic Institute has been used for a number of years to evaluate the economics of various types of electric generating technologies. The model consists of two segments: an optimal generation planning program (OPLAN), and an electric utility financial simulation program (RPIFSM). Inputs to the model include a complete description of the utility's financial status and generating capability, including load growth, fuel mix, taxes, rate of return

---

9/ Wall Street Journal, August 31, 1982, p. 5.

and many other factors. Values are assumed for a number of key parameters, and the financial and generating behavior of the utility is projected over a 20-year period. A number of indicators are computed, the most important being the cost of generating power for the entire system, in cents per kilowatt-hour, over the study period, and the coverage ratio for each year.

The model was first run using data for the New York Intertied System, which has approximately 28,000 megawatts of capacity. It was found that with such a large system, even with very low rates of load growth, the advantages of building small units were lost in the need to add large amounts of capacity each year. Out of this experience a basic "reference" case was developed, using the original data of the New York system, but cutting the size of the system to one-fourth, or about 7,000 megawatts, and adjusting the original data as necessary. The growth rate of the smaller system was also reduced from the original projected rate, to something less than 1 percent per year.

The Reference Case

The Reference Case thus consists of a utility system with the basic characteristics of the New York Intertied System, but consisting of approximately 7,000 megawatts, and growing in load at a rate of less than 1 percent per year. It was then assumed that the utility would meet its need for new capacity under those load growth conditions in two ways: first, by building 400-megawatt nuclear units, and second, by building 1,200-megawatt units.

A third way would be joint ownership of large plants. This is an option that has been used frequently, and while in many cases it has worked very well, there have been difficulties in others, arising from different load growth and financial conditions among the partners, from different treatment by the several rate commissions, and from the need to distribute the output of the plant based not only on the percentage of ownership but also the needs of the individual utilities at any one time. Another option is purchased power from other utilities. This practice is also widespread, particularly in times of excess capacity such as the present. Both joint ownership and purchased power would be options that would compete with the choice to build a small unit.

In the reference cases, inflation was assumed throughout the 20-year construction cycle to be 7 percent per year. This parameter was not varied in subsequent cases. The interest rate in the reference case was 10 percent, and this important input was one of the parameters that was changed in later cases.

The New York system's capacity is approximately 50 percent oil-fired, and this factor has a considerable effect on the relative cost of small and large nuclear units. One of the advantages of a small unit in a low-growth situation is that it can more closely match the need for capacity: a large unit may not be fully needed for a number of years after it is first brought on line. This advantage is weakened, however, if the large nuclear unit makes it possible for the utility to reduce its consumption of expensive oil and still meet its load requirements. The fuel mix of the utility is thus important in judging the economics of small nuclear units. In subsequent cases the oil-fired capacity was assumed to be coal-fired, thus reducing the advantage that the large nuclear units have in replacing expensive oil.

In computing the costs of building small and large nuclear units, it was assumed that the capital cost of the 400-megawatt units was 12 percent greater, in dollars per kilowatt of capacity, than the 1,200-megawatt plants. This differential is substantially less than the old "Six-Tenths Power Law" 10/ assumed, but is in line with the estimates that DOE has made in its development

---

10/ See footnote 1 on page 2.

of a small reactor. In later cases the cost differential was doubled, to 24 percent, and decreased, to 7 percent.

Two variables that were not varied were capacity factor and construction time. Both the 400-MW units and the 1,200-MW units were assumed to operate at a capacity factor of 65 percent, and it was assumed that it took 8 years to build a plant. (See pp. 24-25 for a discussion of the decision not to vary capacity factor and construction time.)

Coverage Ratios

One of the measurements of a utility's financial health is the coverage ratio, which is the amount of revenue the utility takes in each year divided by the interest it must pay out. When interest rates are very high, and sales of electricity are low, a major construction project such as a large nuclear power plant can bring the coverage ratio to a very low point. If the ratio drops below 2.0, the utility has difficulty raising money in the bond market; in fact, some utilities are prohibited by bond indentures from going into the market if the coverage ratio drops below 2.0 or some similar level. In general, the financial health of the utility affects the amount of interest it must pay for the money it raises, and can even prevent it from raising money at all.

Financial constraints have played a significant role in the many deferrals and cancellations of both nuclear and coal units over the past decade. 11/ The coverage ratio is thus an indicator, although a rather qualitative one, of the difficulty a utility may have in building a powerplant. For that reason,

---

11/ U.S. Department of Energy. Energy Information Administration. Nuclear plant cancellations: causes, costs and consequences. (DOE/EIA-0392) Washington: April 1983. See also Idem. Delays and cancellations of coal-fired generating capacity. (DOE/EIA-0406). Washington: July 1983. For the 100 nuclear units cancelled between 1972 and 1982, a lower forecast of load growth was cited as a reason in 52 cases. Financial constraints were cited in 44 cases; in 17 of those load growth was not a factor.

coverage ratios were calculated by the RPI model in each case. Along with cost of power production in cents per kilowatt hour, the coverage ratio was a major indicator of the relative advantage of building small and large nuclear units.

Sensitivity Cases

Having established a reference case, the next step was to test the importance of various factors that contribute to powerplant costs.

The four factors that were tested were interest rates, fuel mix, cost differential between 400-MW and 1,200-MW plants, and growth in load. In each case, only the factor under investigation was varied, with all other inputs kept the same as in the reference cases. For interest rates, the reference case value was 10 percent per year; three cases were run in which interest rates were successively 7 percent, 13 percent and 16 percent. To test the sensitivity of the model to the oil dependence of the utility, all existing oil capacity was assumed to be coal-fired, with its much lower fuel cost. Finally, the rate of increase of load was assumed to be three times greater than in the reference case,approximately 2.6 percent per year--the rate actually projected for the New York system when the data were input into the model. This greater growth rate (for a 7,000-MW system) required that an additional unit be brought on line every one or two years for the 400-MW case, and every four years for the 1,200-MW case.

RESULTS: REFERENCE CASES

The results of the model runs were measured by two variables: the cost of power production (including a return on investment) in cents per kilowatt hour, and the coverage ratio. These variables were computed for each year of the 20-year cycle. Average values were computed, and in the case of the cents/kwh, a levelized cost average, adjusted on the basis of the interest rate paid in each case, was also calculated.

In all cases, the difference in power production cost for the 400-MW and the 1,200-MW construction program was quite small. This is because the costs were calculated for the power production of the entire utility system, not just the output of the new plants. Thus if the average system cost of power production over the study period is 9 cents/kwh,and the newly constructed capacity represents a quarter of the system, and capital costs are 75 percent of production costs of the new plant (these are illustrative assumptions), then a 12 percent differential in capital costs for the new plants would result in a difference of a little more than 2 mills per kwh. 12/

With this illustration in mind, let us look at the results when the cost differential between small and large units is introduced into the complex financial world of an electric utility. Table 1 gives the results for the two reference cases: Case 1.1 using 400-MW plants, and Case 1.2 using 1,200-MW plants.

In the 400-MW case, the levelized cost over the 20-year study period was 9.84 cents/kwh. In the 1,200-MW case, it was 9.75 cents/kwh. Thus in the reference cases, the larger units maintained a degree of their assumed economy of scale in the utility environment. The coverage ratios, however, were significantly different. For the smaller, 400-MW additions, the ratio varied relatively little, and never dropped below 3.0. For 1,200-MW additions, it dropped below 2.0 the year before the first unit is brought on line, and showed another, lesser decline before the second unit became operational. In the middle of the study period, after the first unit was finished

---

12/ 9 cents x 25% x 75% x 12% = .2025 cents

TABLE 1

REFERENCE CASES: CENTS/KWH AND COVERAGE RATIO

Year	Case 1.1 (400-MW)		Case 1.2 (1,200-MW)	
	Cents/kwh	CR	Cents/kwh	CR
1979	6.11	3.38	5.96	3.12
1980	6.50	3.53	6.34	3.15
1981	6.99	3.77	6.81	3.28
1982	7.45	3.85	7.23	3.17
1983	7.88	3.69	7.61	2.80
1984	8.27	3.33	7.95	2.31
1985	8.70	3.01	8.39	1.96
1986	9.49	3.55	9.83	3.06
1987	10.27	3.69	10.64	3.54
1988	10.77	3.47	11.22	3.84
1989	11.41	3.21	11.91	4.18
1990	12.30	3.55	12.69	4.58
1991	13.37	3.71	13.42	4.93
1992	14.05	3.53	14.16	5.17
1993	14.78	3.24	14.94	5.34
1994	15.81	3.56	15.72	5.33
1995	17.12	3.75	16.42	4.75
1996	17.95	3.62	17.06	3.77
1997	18.82	3.31	17.77	2.91
1998	20.12	3.67	19.81	3.73
Maximum:		3.85		5.34
Minimum:		3.01		1.96
Average:	11.91	3.52	11.79	3.75
Levelized:	9.84		9.75	

and before large expenditures were necessary for the second, the coverage ratio rose to a peak of 5.3.

RESULTS: SENSITIVITY CASES

Cases 2,3, and 4 test the sensitivity of costs and the coverage ratio to changes in the cost of money used in construction. In Cases 2.1 and 2.2, interest rates were set at 7 percent instead of the 10 percent of the reference case; in Cases 3.1 and 3.2, interest was 13 percent; in Cases 4.1 and 4.2 it was 16 percent. In each case, all other parameters were the same as in the reference cases.

Table 2 gives the results of these variations. With 7 percent interest rates, the cost was 9.25 cents/kwh in the 400-MW case, and 9.12 cents/kwh in the 1,200-MW case. The difference thus increased slightly as the interest rate dropped. At 13 percent interest, the cost was 10.49 cents/kwh in the 400-MW case, and 10.46 cents/kwh in the 1,200-MW case. With the interest rate at 16 percent, the cost in the 400-MW case was 11.21 cents/kwh, and for the 1,200-MW case it was 11.25 cents.

TABLE 2

LEVELIZED COST OF POWER AND MINIMUM COVERAGE RATIO FOR VARIED INTEREST RATES

Case	Interest Rate	Levelized Cost	Minimum Cov. Ratio
2.1 (400-MW)	7 percent	9.25	2.79
2.2 (1200-MW)	7 percent	9.12	2.02
1.1 (400-MW)	10 percent	9.84	3.01
1.2 (1200-MW)	10 percent	9.75	1.96
3.1 (400-MW)	13 percent	10.49	3.25
3.2 (1200-MW)	13 percent	10.46	1.93
4.1 (400-MW)	16 percent	11.21	3.50
4.2 (1200-MW)	16 percent	11.25	1.91

In these cases, the 12 percent cost advantage of the large plants was narrowed as the interest rate increased, and in the 16-percent cases it was entirely overcome in the financing of the new construction.

The coverage ratios followed a similar pattern. With interest rates at 7 percent, the ratio did not drop below 2.0 for the 1,200-MW case, although its minimum value was significantly less than the 2.8 of the 400-MW case. At 13 percent and 16 percent, however, the ratio for the large additions did fall below 2.0 in the year before the first unit was brought on line, reflecting the financing difficulty involved in building large plants.

Cases 5.1 and 5.2 (Table 3) show the importance of dependence on high-priced oil on the cost of power production. When all oil-fired generation was replaced with lower-cost coal, the cost of generation for the utility system was 9.19 cents/kwh in the 400-MW case, and 9.18 cents/kwh in the 1,200-MW case: virtually the same for both. The coverage ratio remained the same for both these cases as in the reference cases, staying above 3.0 in Case 5.1 and dropping below 2.0 in Case 5.2.

TABLE 3

LEVELIZED COST OF POWER PRODUCTION:
OIL REPLACED BY COAL

Case	Description	Levelized Cost (Cents/kwh)
1.1	Reference Case, 400-MW	9.84
1.2	Reference Case, 1200-MW	9.75
5.1	Oil Replaced by Coal, 400-MW	9.19
5.2	Oil Replaced by Coal, 1200-MW	9.18

Cases 6 and 7 tested the effect of changing the assumed capital cost difference between the 400-MW and the 1,200-MW units. In Case 6.1, the difference was assumed to be 7 percent, rather than the 12 percent of the reference case. In Case 7.1 it was set at 24 percent, twice the reference case differential. The results are shown in Table 4. In neither case did the levelized system cost differ notably from the reference case: at 7 percent cost penalty

(Case 6.1) it was 9.82 cents/kwh; at 12 percent (Case 1.1) it was 9.84 cents, and at 24 percent (Case 7.1) it was 9.89 cents. In all these cases the cost was greater than the 9.75 cents/kwh of the 1,200-MW reference case (Case 1.2).

TABLE 4

LEVELIZED COST OF POWER PRODUCTION UNDER
VARIOUS ASSUMED SMALL PLANT COST PENALTIES

Case	Description	Levelized Cost (Cents/kwh)
6.1	400-MW; capital cost per KW 7 percent greater than 1,200 MW	9.82
1.1	400-MW; capital cost 12 percent greater (Reference Case)	9.84
7.1	400-MW; capital cost 24 percent greater	9.89
1.2	1,200-MW (Reference Case)	9.75

A final set of cases tested the effects of a higher rate of load growth. With load increasing at three times the rate of the reference cases, it was necessary to assume that new units would be added more frequently---every four years for the 1,200-MW units, and every one or two years for the 400-MW plants.

A more rapid growth rate meant that the full capacity of the large 1,200-MW units would be utilized more quickly, and the financing burden, though higher overall, did not have the high peaks and low troughs that occurred when there were 12 years between plants. As a result, the power production cost difference between the 1,200-MW and 400-MW cases widened, compared to the Reference cases. For 400-MW units (Case 8.1), the cost was 9.31 cents/kwh, while for 1,200-MW units, it was 9.14 cents. The coverage ratio, however, was still unfavorable for the 1,200-MW additions, falling below 2.0 in the year before the startup of the first plant.

ANALYSIS OF RESULTS

The modelling exercise described in the preceding sections leads to a number of tentative conclusions. These include:

Financing Large Plants. Building 1,200-MW plants causes financial difficulties, as indicated by the coverage ratio, for the utility, while building 400-MW plants does not. In all cases, including those with rapid growth and with low (7 percent) interest rates, the coverage ratio dropped close to or below 2.0 for the year before the first 1200-MW unit became operational. In the 400-MW cases, the Coverage Ratio never went below 2.00, and in most cases was above 3.0.

Cost Effects of Plant Size. Economies of scale do not seem to have as great an impact on the cost of producing power in the utility's total economic environment as other factors—such as interest rates and fuel mix. The levelized costs of power in the 400-MW and 1200-MW reference cases (Cases 1.1 and 1.2) differed by .09 cents/kwh; but changing the assumed interest rate from 10 percent to 7 percent, for instance, reduced costs by .59 cents in the 400-MW case (Cases 1.1 and 2.1) and .63 cents in the 1200-MW case (Cases 1.2 and 2.2). When the capital cost differential was varied (in Cases 6.1 and 7.1) the cost of power changed relatively little: doubling the assumed economy of scale from 12 percent to 24 percent (Case 7.1) led to an increase of only .05 cents/kwh in the cost of power for 400-MW plants, and reducing it to 7 percent (Case 6.1) had a similar effect in the other direction.

Effect of Oil Dependence. The amount of oil-fired generation in a system can have a significant effect on preserving what economies of scale exist for large plants. This is because a large nuclear unit, once built, will allow the utility to meet its load requirements without burning as much oil. The load factor on the oil units is thus reduced, but oil generation, unlike nuclear power, has relatively low capital costs but very high fuel costs. Thus, idle oil generating capacity is a relatively minor cost factor. Coal-fired generation, on the other hand, has higher capital costs than oil (although not as high as nuclear), and its fuel costs are less than oil (although again not as low as nuclear power). The result is that the penalty for idle coal generating capacity is higher, and the savings from coal fuel costs are less. The result, as shown in Cases 5.1 and 5.2, was that the assumed cost advantage of the large nuclear units was lost when all oil generation was switched to coal.

Interest Rates Significant. Interest rates have an effect on the relative cost to the system of building small or large nuclear plants. Varying interest rates from 7 percent to 16 percent caused decreasing cost differences between the 400-MW and 1,200-MW cases, with the cost actually higher for the large plants when interest rates were 16 percent.

High Growth Aids Large Plants. More rapid growth in load increases the advantage of large plants over small. Tripling the growth rate (from less than 1 percent per year in the reference cases to approximately 2.6 percent per year in Cases 8.1 and 8.2) resulted in a difference of .18 cents/kwh in the production cost for 400-MW and 1200-MW cases, compared to .09 cents/ kwh in the reference cases. The lesser importance of the economy-of-scale effect is once again demonstrated by these cases: the absolute value of the levelized cost in the high-growth case was .53 cents/kwh lower than in the reference case for the 400-MW plants, and .61 cents/kwh lower for the 1200-MW plants. However, the negative effect on the coverage ratio that was present in the 1,200-MW reference case remained when load growth was tripled.

Untested Parameters

In modelling a complex phenomenon like utility construction projects, it is necessary to make assumptions that leave untested a number of factors.

Because of this, the results of the model calculations, while quantitative, are only illustrative of the relative importance of the factors that are tested. It would be an unwarrantable conclusion, for instance, to state that a utility in the situation similar to that described in the reference case will find it cheaper to build 400-MW plants when the interest rate reaches between 13 percent and 16 percent. It is valid, however, to conclude that the economies of scale of large nuclear powerplants are relatively small in the total utility economic environment, and that they are eroded by high interest rates, by lack of oil generation to back out, and by low rates of growth in load.

Some of the factors left untested by the model are simply unmeasurable; others are so complex that they cannot be incorporated in the model in a practical sense.

Unvaried Parameters. One of the complexities that removes the model farthest from reality is the variable quality of some of the parameters involved: most particularly, growth rates, interest rates, inflation, and the cost of various inputs. Such difficulties are common to modelling and projections of future economic behavior, but often they have a way of averaging out to cancel their erratic behavior. In the present case, however, variability would be expected to have a significant effect on the outcome, as a look at the year-by-year data in Table 1 indicates. Especially in the case of the 1,200-MW construction program, certain costs are lumped in specific years. An exceptionally high interest rate in those years, or a drop in electricity sales, could sharply affect the average power production cost or the financial status of the utility in a way that the model could not measure.

Construction Times. One simplifying assumption made in the model was that construction of either a 400-MW unit or a 1,200-MW unit takes 8 years.

This assumption flies in the face of the conventional wisdom that construction takes 10 to 15 years, and that large plants should take longer to build than small ones. However, the history of nuclear construction over the past decade shows that the stretched-out construction times of that period--with some important exceptions, such as the Diablo Canyon project--were primarily the result of slow load growth and financial difficulties rather than of licensing and construction difficulties. In one case where there was demand enough to make rapid construction possible—the St. Lucie plant in Florida—the plant was brought on line in less than 8 years. In light of the intrusion of load and financial problems in construction time calculations, it is effectively impossible to say how long it should take to build a nuclear plant when there is a market for its power and the utility has the financial strength to pursue the project. Eight years does not seem an unreasonable assumption in the absence of a meaningful historical figure.

The same type of reasoning holds for the assumption of equal construction times for large and small plants. Historical data may indicate that smaller plants have taken less time to build, but most of the small plants were completed well before demand-induced delays of the mid-1970's, whereas most of the larger ones were not.

It might have been useful to test the sensitivity of power costs to construction time, but this proved impractical. The model required that any project started had to be finished in the 20-year period, which did not leave enough flexibility to vary the construction programs in the two cases in a meaningful way.

Capacity Factors. Another broad assertion about nuclear power is that large plants are less reliable that small ones. Investigation of this issue reveals few data and widely varying claims. In view of the controversy it did not seem advisable to make the assumption that the capacity factors of small units would be greater.

Unmeasurable Factors. The computer model used in this study measured both the cost of producing power and the financial effect on the utility of construction expenditures. Obviously these two indicators are related: the amount of interest paid by a utility on a new bond issue, for instance, is affected by its financial health. It was not possible to measure this relationship in a meaningful way, however. Even less measurable was the effect of uncertainty in load, income and licensing on the utility's financial situation, even though uncertainty has become both a burden and a way of life for today's electric power industry. There is no doubt, however, that uncertainty becomes a greater problem as the size of the project increases.

SUMMARY CONCLUSIONS

The modelling exercise performed for this study indicates strongly that small nuclear power plants could have a market. In all cases, the cost of producing power for the whole system, assuming new load was met by building the small plants, differed only in tenths of a mill from the cost when large units were built. While cost differences of this magnitude can build up to sizeable amounts on an entire system--for a 7,000-megawatt utility they would be on the order of $20 million per year—they are much less than the differences caused by other factors such as interest rates or fuel mix.

If a utility can meet its load requirements by constructing 400-megawatt plants to come on line spaced 4 or 5 years apart--for the 7,000-megawatt utility modelled in this study, that means a growth in load of less than 1 percent per year--then the higher capital cost of the small plant, not very significant in total cost calculations in any case, is strongly compensated for by the more level financing reqirements and lack of periodic overcapacity that typifies large plant construction. If interest rates are very high, in fact, the cost penalty is entirely overcome.

The existing fuel mix of the utility was also found to be a significant factor. In the reference cases, the utility's capacity was assumed to be more than 50 percent oil-fired. This gives an advantage to the large-plant case, since the excess nuclear capacity can be used to back out expensive oil. When it was assumed that the existing oil-fired capacity was changed to coal, system costs were virtually identical in the 400-MW and 1,200-MW cases, despite the assumed 12 percent capital cost differential.

The coverage ratio, an indicator of the utility's financial health, signalled the difficulties involved in large construction projects. In each case the building of large nuclear units caused the coverage ratio to fall lower than it did when demand was met by building small plants. In many of the large-plant cases it fell below 2.0, the level at which some utilities are prohibited from raising new debt. In contrast, the coverage ratio did not fall below 2.0 in any small-unit case, and in most cases it stayed above 3.0. It is impossible to turn a measure of the coverage ratio into a cost-of-production figure. But there is no doubt that, in times of uncertain growth and high interest rates, the coverage ratio and the financial situation it reflects will have an important effect on the utility's cost of money, and even its ability to raise cash at all.

At higher growth rates, or for very large utility systems, the advantage of small units measured by the model in this study largely disappears. Under those circumstances, a utility would have to add a smaller plant every year or so, and the financing advantages of the small units is lost. Nevertheless, the coverage ratio, and the financial condition it reflects, remained consistently better for the small units than for the larger ones.

Mrs. **Lloyd**. Well, thank you very much for your very fine paper, "Economic Potential of Smaller Sized Nuclear Plants in Today's Economy."

Dr. Behrens, did your study include any study on the overseas market, such as the potential for the small reactors?

Dr. **Behrens**. No, Madam Chairman, the study didn't address the foreign market. One would assume that, in foreign countries, you would have a larger demand for smaller sized plants since they're starting at a smaller level; but the essential message of this study was that it is the financial conditions of the individual utility that determine the cost of the plant, so that your economies of scale under the right conditions are wiped out by financing difficulty. But these are very specific to the utility, so we have only U.S. utilities in our study.

Another aspect, of course, is that the U.S. utilities are in the private money-raising market, whereas many foreign countries—the utility industry is Government-run, Government-funded, or it's a Government subsidiary so they have different problems in raising capital.

Mrs. **Lloyd**. Dr. Behrens, if the construction for a larger nuclear plant perhaps could be shortened to France's construction time, 4 or 5 years to build a plant—if we could limit the timetable for construction of the larger plants, how would this impact your projections?

Dr. **Behrens**. For our project, we assumed that the construction would be the same for both large and small plants, and we assumed an eight year construction period. It was not practical to vary the construction time within the limits of the computer's idiosyncrasies so we couldn't experiment with that. But I would say that the critical variable is not so much how long the project is on the books and under construction, as how fast you are going to utilize the power that is produced. What has got the utility industry into difficulties is that they started out in the early 1970's growing at 7 percent a year and expecting to have to continue that, and then found that they were growing at 2 percent a year; so the plants that they expected to need within 5 years they didn't need for 17 years. Now, when you stretch out your construction for such a long period, then you're not getting a return on the money that you put in at the beginning of it. I don't know whether that really addresses——

Mrs. **Lloyd**. The point that I was making was that you get a quicker return on your investment——

Dr. **Behrens**. Yes.

Mrs. **Lloyd**. If you can cut the construction time down in half, perhaps.

Dr. **Behrens**. Yes, and I fully agree with that. The point that I am trying to make is that you have to need the power so that it doesn't do you any good to build a plant in 5 years if your demand is not going to be there to sell the power from it for another 10 years.

Mrs. **Lloyd**. Well, I think we've all conceded that our electricity growth has paralleled the growth in our economy. We certainly are looking forward, we hope, to a healthy economy.

Dr. Behrens. Certainly, that's true. And if you're going to add power at a rapid rate, if you're going to grow at 3, 4, or 5 percent a year, you have a fairly large utility, then you're going to look at the large plants because that's the only way you're going to meet that demand. If you anticipate that you're not going to grow that fast, then you're going to be looking at smaller plants; and in either case, you want the construction time as short as possible. No doubt about it.

Mrs. Lloyd. How sensitive are your calculations to the type of reactor or the reactor design? In other words, could this model be used to study the economics of the smaller modular breeder reactor including, perhaps, the fuel cycle costs?

Dr. Behrens. It's essentially independent of the technology; we merely assumed that you had a reactor that was only 12 percent more expensive per kilowatt than your standard LWR. We also, however, varied that assumption; we assumed that you could get one for 7 percent more, and also one that was 24 percent more. We found in each case that varying that didn't make much difference in the cost of power, so that the actual original capital cost of your powerplant doesn't seem to make that much difference compared to other factors, such as whether your interest rate is 7 percent or 15 percent. That makes a tremendous difference in the cost of power.

Mrs. Lloyd. So basically, if we establish that electricity growth is going to parallel the growth of our economy, then that takes care of the demand. So, basically, the time element is the return of the money and the rate of interest?

Dr. Behrens. That's correct.

Let me try and clarify. I think I was muddling here a little bit; let me try and clarify my point.

It is very, very difficult to make a rational decision in an investment if you're going to stretch that investment over 10 or 15 years. You cannot predict what's going to happen that far down the road. So that any healthy utility industry is going to have to shorten the amount of time they have to predict, and the amount of time they have to spend constructing powerplants. Whether they are going to build small ones or large ones, they have got to get that time down to a reasonable amount. My point is that they got sandbagged earlier in the decade by anticipating that we would need a lot of power in the next 5 or 6 years, and then the power demand dropped off and they haven't needed that power; and as has been mentioned, we've had an excess capacity. That can't go on. We can't have a healthy industry, a functioning industry that's getting stretched out like that. And that, I think, is really basically where all the cancellations and the financial difficulties have happened.

Mrs. Lloyd. The position of this Member of Congress is that, certainly, the Federal Government has a role to play in R&D where the private sector cannot pick up this area; because I don't want to invest in a company, or corporation, or utility if I would not get a return for my money in under 20 years. That doesn't make sense, and this is really the topic of conversation that I had with Dr. Keyworth last week when he was here before the full committee, that there is indeed a role for the Federal Government to play in our energy program because this is not an area where the private sector can pick up research and development to put our energy programs on line.

But the nuclear industry also has taken a position that regulatory and licensing requirements have added significantly to the cost of our nuclear powerplants. Now, your paper indicated that the impact of this factor on the cost is rather uncertain. Would you clarify that, or would you like to expound more on this? Would licensing reform help reduce the cost of building nuclear powerplants?

Dr. **Behrens**. Well, it may or may not, but my study did sort of finesse that question. What we said, since we're comparing small and large nuclear plants, we didn't go into the question of whether an improved licensing situation would aid small plants more than large ones. That's an interesting topic; we just didn't get into that.

Mrs. **Lloyd**. Dr. Dugan, I think, has a comment he wants to make.

Dr. **Dugan**. Is it true, then, Dr. Behrens, that given the fact you chose the same construction time period, if one went to a certification procedure with plants built in a factory and they were certified, and you cut the time way down, that would favor small plants if you include that in your model? You didn't treat either one of them?

Dr. **Behrens**. I would think that, in general, a shorter construction time would improve the economics, yes; but we didn't measure it that way.

Mrs. **Lloyd**. One final question from this Member, Dr. Behrens. How can the nuclear power option be preserved, in your estimation, as a viable energy supply source for this country?

Dr. **Behrens**. Well, I guess that's a little beyond the scope of the study that I did, and with your permission I'd rather not answer that one.

Mrs. **Lloyd**. Thank you very much.

Are there any other questions from the committee staff?

[No response.]

If not, I thank you very much for your testimony. This committee will meet again at 9 o'clock in the morning for further hearings.

Thank you very much for your participation and for your interest in this hearing.

[Whereupon, at 2 p.m., the committee recessed, to reconvene at 9 a.m. Wednesday, February 8, 1984.]

1985 DEPARTMENT OF ENERGY AUTHORIZATION

WEDNESDAY, FEBRUARY 8, 1984

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Research and Production,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9 a.m., in room 2318, Rayburn House Office Building, Hon. Marilyn Lloyd (chairman of the subcommittee) presiding.

Present: Representatives Lloyd and Chandler.

Staff present: John Dugan, Ron Williams, Nelson Milder, Dave Clement.

Mrs. **Lloyd**. The subcommittee on Energy Research and Production will come to order.

Good morning, ladies and gentlemen. It is good to welcome you here this morning. Today I strongly urge the Department, as I encouraged the outside witnesses yesterday, to look upon this fiscal year 1985 budget as one of great opportunity. Chairman Fuqua and I have been pressing for a bold and innovative approach by the DOE since last fall. I'm very pleased to note that Dr. Brewer is also speaking of turning to new and alternative strategies for insuring future nuclear vitality. Our overall message is clear: there is no time for business as usual.

As I pointed out to the President's Science Advisor last week, the nuclear fission R&D budget is down roughly 50 percent from the last Carter budget. We have the paradoxical situation that a President who is well-intentioned about his support for nuclear power simply cannot deliver in today's economic and regulatory climate. As a result of soaring costs and a growing public perception of safety shortcomings, public acceptance of nuclear power has diminished significantly during the Reagan administration.

Many of us are genuinely sympathetic to licensing reform, but it is not very productive for us to deliberate upon these issues at length in this committee. The job of this committee is to see that we have a balanced and a well-crafted nuclear fission R&D program. Chairman Fuqua and I have pushed for an inherently safe reactor initiative with Secretary Hodel in November, mindful of all the difficulties besetting the industry. We believe that one simply cannot hope and pray that the regulatory climate will improve; nevertheless, something imaginative must be done in the R&D arena in face of the evidence that no one has ordered a new plant for 6 years and cancellations of plants on order and under construction have continued unabated. We also wrote Dr. Brewer last month to outline all of our recommendations for the restructuring of the breeder technology program. We did this after considerable discussion between the staff and DOE program managers. It is no secret that the Chairman and I are interested in the redistribution of resources across the nuclear fission program. We cannot put all of our technological eggs in one basket. We must fund work on advanced reactor concepts which can be built and licensed in a simpler and certain manner, and we must support a space effort with sufficient resources to make it technologically ambitious.

This is no time for "whistling in the dark" and simply hoping that things are going to get better. We have lots of work to do and we must try to involve the best minds in the country who have any interest in reviving the nuclear option. In this respect, I think that we must seriously consider how we might augment the university role in the nuclear fission R&D programs. We have traditionally relied on the universities to come forward with fresh and innovative ideas, unhampered by short-term constraints or deeply-ingrained biases on nuclear power development. We must do all this with renewed vigor and a sense of commitment to save the option through high quality performance.

I am very pleased to see that Dr. Brewer and his people have shown us that they are thinking innovatively, both in their budget justification for the HTGR programs as well as in encouraging advanced breeder designs. It is clear that we need greater funding for a broad program but that will be difficult in this budget climate. And I suggest that we begin work in earnest with these fiscal year 1985 budget hearings. And I'm certainly looking forward to hearing the DOE view on the opportunities that lay before us.

Dr. Brewer, we're awfully happy to have you with us this morning, and your fine people that work with you' and we now turn the morning's proceedings over to you to hear your suggestions and your approval and your opinions.

Thank you.

STATEMENT OF DR. SHELBY T. BREWER, ASSISTANT SECRETARY FOR NUCLEAR ENERGY, DEPARTMENT OF ENERGY

Dr. **Brewer**. Thank you, Madam Chairman. As always, it's a delight to appear before your committee. I have a long and rather dry statement which I will offer for the record, but I thought, rather than inflict that on you by reading it, I would like to make a few points orally to place it in the context and to bring some policy perspective and syntax to the subject.

Mrs. **Lloyd**. Without objection, your complete statement will be made a part of the record and you may summarize or proceed as you wish.

Dr. **Brewer**. Madam Chairman, I believe that you and Chairman Fuqua are to be complimented for your courage and endurance in structuring your hearings as you have with an emphasis on advanced thinking rather than on the specifics of program and budget. And I believe that you are to be applauded for your choice of witnesses yesterday and today.

I sense that we are reaching here, as the Department is, for new themes, new directions, new solutions, and I would hope, perhaps, some new markets for nuclear power.

Several events in 1983 and early 1984 have propelled us toward a very thorough reexamination of our current and future nuclear paths. The big event in 1983 was the rejection by Congress of the Clinch River breeder reactor project. More recently we have seen a wave of nuclear cancellations in the past 2 or 3 weeks; and other plants, although not canceled, in serious trouble although essentially complete. And I think it's appropriate that we engage in this dialog. Something is wrong, something is drastically wrong and we should fix it; we must fix it. But I do urge that we not rush to some sophomoric judgment that nuclear power is dead. It is not dead; we have over 80 plants operating in this country, delivering about 13 percent of the Nation's electricity, more than any other nation in the world; we have the most mature nuclear infrastructure in the world; our nuclear products, our nuclear fuel and reactors are the best in the world. We have, in nuclear power, an unparalleled safety record. In fact, it's exactly perfect. Nuclear power was invented in this country and has been applied very vigorously in other countries. But it must be admitted that the option, nuclear power in the United States, is in a state of severe recession and has been for about 10 years. We have had no new orders in the past 6 years. There have seen numerous cancellations over the past 10 years. The recent wave of cancellations and red ink involve nearly completed plants, and we are now seeing a retrenchment from nuclear power by the business and financial community.

Those utilities which have nuclear powerplants operating but none under construction, none in the licensing process, are doing better than the national average economically in terms of bus bar costs and in terms of financial health of their utility. But those utilities with nuclear plants under construction are doing worse than the national average.

Our economic record is excellent for the population of plants operating and our safety record is unparalleled. And this reinforces my view that the institutions, the way we conduct business, not the technology, is the problem. The problem is institutional, financial, political in character and for that reason I urge that we not rush to judgment on a new technological era, but that we try to match the institutions to the machine as well as matching the machine to the institution.

Please do not infer that I am being closeminded and tradition-bound; I am not ruling out a new class of reactors, I am encouraging that we examine very carefully the prospect of a new class of reactors better suited to the institutions which have to build, manage, operate, and regulate them.

An example of a more deliberative approach is our proposal in our advocacy of the High Temperature Gas Reactor (HTRG). To start with, the HTGR option is one which the customer, the utilities, have said they wanted; and the Department has, for many years, promoted and conducted an R&D program in high temperature gas reactors. The HTGR has many unique features that are extraordinarily attractive. It has a large heat sink which is beneficial should the reactor get into an off-mode accident situation. It has a benign coolant, a nonradioactive coolant, meaning that one can maintain the equipment essentially hands-on. It has a very long response time for accident conditions. It has a single-phase heat transport coolant. One does not have to worry about boiling and two-phase flow and the control apparatus that that entails. And it has, moreover, a high temperature capability. It can reach nonelectrical markets which water and the liquid metal machines cannot reach.

And I believe that it is especially matched to a market which needs small increments and a host which does not have an indigenous nuclear infrastructure—smaller utilities and developing countries. It is an ideal export product.

For all of these reasons we believe that it is prudent and within the appropriate Federal role to develop a modular, or small, HTGR to the point where the private sector picks up the responsibility for demonstration and deployment.

Madam Chairman, let me return to the point of achieving a match between the institutions and the machines. Clearly, something is wrong and has been wrong, and it's not getting better. I believe the problem is basically institutional less technical than institutional; it's the way we do business, the way risks are taken, the way benefits are distributed, the checks and balances in the entire system, and so forth. France has been able to stay with the current large light water reactor deployment course without any apparent trauma, and my point is this: We must either make our institutions larger and more resilient, or make the machines smaller. France has one utility which serves the entire country; it's about as large as one or two of our largest utilities in this country. The resources of these utilities here and EDF in France can handle large financial and technological commitments in an intensively regulated environment.

I am urging not a surrender nor a retreat from our large light water reactor product line; I am urging that we instead open new markets for nuclear power in smaller increments.

There are several attributes of smaller units that warrant careful exploration and research. First of all, smaller units are better matched to supply planning to the demand curve. Second, smaller units can be standardized readily, and one can achieve economies of mass production. Central shop fabrication of modules or small reactor units are more amenable to quality assurance, better quality assurance; and quality assurance is one of the major problems impeding nuclear power today, as we've seen in the last 3 or 4 weeks.

With smaller units there is better investment protection. You're not betting your company by ordering a nuclear unit. If the unit goes down with a forced outage for whatever reason, it can be a smaller fraction of your total grid generating capacity; and it has many other attributes.

I am struck by the fact, Madam Chairman, that the United States has not moved to standardization sooner. We have over 80 plants in this country, operating, and they are largely custommade, and they are largely 80 different designs. And we have a totally heterogenous and random regulatory process; it's a swarm of ants seeking a mission.

I'm not entirely convinced that the economies of scale, the traditional doctrine, can be overcome by the economies of mass production. I think—I don't know—that the answer is probably yes. I believe that if we had it all to do over again, that we would have standardized, modularized, and mass produced in the first place rather than to treat each unit as a custom product, different—each with different flags and bells and whistles, each product a monolith, a pyramid to be sculptured by an ant farm of artisans and regulators.

It seems that each nuclear powerplant under construction these days is a sociopolitical phenomena. They require cities to be erected to support their erection; giant bureaucracies which have to be established to coordinate with one another.

My proposal, Madam Chairman, is that we move deliberately with an intent to open a new market, a new frontier for nuclear power, and an effort which does not threaten what has been achieved and proved to be beneficial to electricity consumers in the past. My budget request includes about $30 million vectored toward innovative concepts. This funding request is found in several of the line items, and I will just briefly summarize.

We have asked for $15 million in the liquid metal reactor account for innovative design, designs well beyond the Clinch River technology and the current technology of France and Japan, designs which offer passive safety concepts. We have asked for $35 million for the HTGR program; about $10 million of that will be applied to a very rigorous, thorough, conceptual design effort on the modular HTGR. We have another $1 million which is in the converter reactor account which we propose to apply to study the PIUS reactor, and we have about $1 million to $2 million to examine the economics and feasibility of small reactors in general for multiple markets.

Another factor that I would like to emphasize and stress, Madam Chairman, is our priority for nuclear licensing reform. As you know, last year we submitted a licensing reform bill. The intent of the bill is to streamline the licensing process, to emphasize safety. The features of that bill allow for one-step licensing; a more disciplined retrofit process; to get away from the pattern we've seen over the years of designing as we go, with a constant interaction with the Nuclear Regulatory Commission. We feel that standardization, which is inherent in all aspects of the bill, will lead to a safer product, a product in which the technical and regulatory resources of the country can be applied to fewer standard products, perhaps mass produced rather than a plethora of individual design considerations.

Madam Chairman, let me turn now to how we have restructured our major expenditure programs. I have said that we are redirecting about $30 million to new product definition and development, and examination of small, innovative design. As you know, the cancellation of Clinch River has caused us to restructure the entire breeder program, the liquid metal program. The program is not, I repeat, is not dead; and it is not dying. We have made several assumptions in restructuring the program. The first assumption is that we shall not be driven by a specific need date; instead, we will work off the technical and economic issues much like the fusion program, in series—in tandem. We will preserve the residual values of the Clinch River experience. And I must say that despite the fact that we did not build the plant and operate it, it's my judgment that we got about 40 percent of our value out of the project through the design, the licensing, the fabrication, and testing of the equipment.

You may have noted that we recently were awarded, by the ASLB, a determination—a recommendation to NRC that the construction permit should be awarded. We're very proud of that.

A third major assumption or touchstone is that we will move aggressively to internationalize the breeder program since we will not be taking the intermediate demonstration step. We will seek a nation that has taken it or who will take that step and use, as leverage, our considerable experience in Clinch River and the base technology program.

Finally, we will be stressing advanced, innovative designs. There are several which merit very careful attention. We have applied, as I said, $15 million in the breeder budget to this effort.

Let me turn now to another subject which is of interest to this committee, Madam Chairman, and that is uranium enrichment. I will be brief and be happy to answer your questions very shortly.

As you know, over the past 10 years the United States went from being a monopoly in the enrichment business world-wide, with 100 percent of the market, to 1981 of having only 35 percent of the total world market. More recently, in the past 12 or 18 months, we began to notice an erosion of our domestic market. We examined this very carefully and very quickly and determined that there were several factors causing this to occur.

First, the foreign exchange rate placed the U.S. enrichment enterprise at a severe disadvantage. One American dollar in 1983 could buy twice as many S.W.U.'s abroad than it could in 1980; the strength of the U.S. dollar placed our business at a disadvantage.

Second, the other phenomena was the secondary market. For many years we and the foreign producers operated under fixed committment contracts; that is to say, the customer has signed up for so many S.W.U.'s per year, and he has to take them or pay for them. Very rigorous contracting terms which leave the utility with very little flexibility. For many years the producers, EURODIF, URENCO and the U.S. were force-feeding the separative work unit into utilities who did not need them because plants had been deferred or slipped or cancelled. For this reason a large excess world inventory, probably 30 or 40 million S.W.U.'s, built up and became the basis for a very aggressive secondary market which could undersell any S.W.U. produced; so our U.S. domestic utilities, who had requirements-type contracts, began to purchase S.W.U.'s on the international secondary market. They could price S.W.U.'s at $80 or $90 per S.W.U., while our production costs were about $140. So we began to lose revenue base and future revenue projections.

I formulated a third factor which contributed to this market erosion, and that was the fact that we simply had not, over the past 10 years, operated this enterprise like a business. It was not market-responsive; we were bound by very rigid interpretations of the 1954 Atomic Energy Act, and so forth. About 9 months ago I suggested a strategy to the Secretary which we now have adopted, the first major element of which is to rationalize, normalize, and stabilize the market. And the major tool for doing so is the new enrichment contract which we have now issued. This contract allows for drying up the secondary market, the excess inventory. It allows for a 30 percent offset by a customer; he can obtain up to 30 percent of his enrichment requirements from sources other than the Department of Energy.

Second, it is a requirements-type contract. It is based on the utility's actual needs, not on what he thought his needs might have been, so we will not continue to feed the world excess, the world glut.

Third, we have established a pricing policy which is a flat $135 per S.W.U. price adjusted only for national inflation and power inflators.

I am happy to say that our response to the market, our market response to the new contract has been quite good; 2 days ago I signed a contract with Duke Power for over $2 billion. It's the largest contract I have ever personally signed. Duke took not 70 percent from the U.S. Department of Energy, but 100 percent. Indications from the rest of our domestic customers are in that direction as well.

Another major market for the U.S. enrichment enterprise is the Far East, and they are beginning to come aboard. I believe that we will achieve, essentially, a home run there.

Mrs. LLOYD. Shelby, what countries in the Far East are you referring to?

Dr. BREWER. Japan and Korea.

Mrs. LLOYD. How many countries have enrichment capacity now?

Dr. BREWER. There are four producers: the USSR, URENCO, EURODIF, and the United States. Japan plans, by the year 2000, to have about one-third of its needs provided by indigenous enrichment capacity; Australia has talked about getting into the enrichment business, but that's not clear.

I think the condition of world over-capacity in enrichment will probably dissuade many countries from getting into that market.

Mrs. LLOYD. Thank you.

Dr. BREWER. It's my belief, and I am very relieved to project, that we have turned the corner in the enrichment crisis. Our basic strategy is to fix the market first, to stabilize the market, and then to design the production strategy in accordance with market needs. We have turned around the earlier philosophy of having the production strategy, the production requirements drive the market. That has led to this downward spiral; we are now listening to the market, we will get a floor on the market, and arrange the production strategy accordingly.

We will also take very major steps to reduce cost, both in the production program and in the construction and research and development programs.

One other thing I would like to mention, Madam Chairman, is the one large growth program in the Department, the remedial action program. That is up from about $100 million to about $150 million, much of which has been added to the uranium mill tailings program. We are working under a 7-year clock; the clock started ticking when the guidelines were issued back in March 1983, and we have kicked off that program, we have projectized it, we have scrubbed the fat out of it. We initiated the program with the Canonsburg site in Pennsylvania and I feel confident that we can complete that program in seven years and get that one off the books.

Another major initiative in the remedial action program is the beginning of activities to decontaminate and decommission the Shippingport reactor.

So while the breeder program is down slightly from the 1984 level, the 1984 base program level, the remedial action program is up somewhat. The converter reactor program, we have requested for the first time in many years a finite, non-zero budget for the high temperature gas reactor. I believe that we are moving in the directions that you and Chairman Fuqua have advised the Secretary and myself; and with that, I would be happy to respond to any questions you might have.

[The prepared statement of Dr. Brewer follows:]

STATEMENT OF SHELBY T. BREWER
ASSISTANT SECRETARY FOR NUCLEAR ENERGY
DEPARTMENT OF ENERGY
BEFORE THE
COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
FEBRUARY 7, 1984

Madam Chairman and Members of the Subcommittee, I am pleased to be here today to discuss the Department of Energy budget for nuclear fission energy programs. Our Energy Supply research and development funding request for FY 1985 is $590.4 million in budget authority, as compared to the $663.4 million appropriated in FY 1984. The requested funds are distributed among the program elements as indicated in the following table.

Program Element	FY 1984 (in millions)	FY 1985 (in millions)
Converter Reactor Systems	$ 92.7	$ 83.5
Breeder Reactor Systems	423.2[1/]	308.1
Advanced Nuclear Systems	34.2	33.5
Remedial Actions	99.0	152.0
Nuclear Waste Technology	14.3	13.3
Subtotal Energy Supply R&D	663.4	590.4
Uranium Enrichment	$2,193.8[2/]	1,675.3
Uranium Enrichment Revenues	-2,105.0	-1,675.3
Subtotal (Net)	$ 88.8	$ 0
Total	$ 752.2	$ 590.4

[1/] Includes $40 million transferred from Uranium Enrichment Program for Clinch River Breeder Reactor termination.

[2/] Includes $130 million of deferred funding; excludes $40 million transferred for Clinch River Breeder Reactor termination.

Before describing these program elements in detail, I will comment briefly on a number of the external factors that have influenced preparation of our FY 1985 budget.

The past year has been a complex mixture of successes and disappointments for nuclear energy. We have a President who strongly supports nuclear power and recognizes it as an essential element of a balanced energy supply for the future. In 1983 three new nuclear powerplants achieved commercial operation status, raising the annual output of nuclear generated electricity to almost 300 billion kilowatt-hours, or about 13 percent of our total electrical generation. Nuclear power continues to provide us with safe, clean energy. Its economics are on a par with coal, and substantially more favorable than oil or gas. In spite of this impressive performance, nuclear power is not considered an attractive investment by the electric utility industry. Six plants were cancelled in 1983--and four more were either cancelled or indefinitely delayed in January of this year. In addition, no new plants have been ordered since 1978. The fact that this disturbing situation is the result of complex and interrelated economic, regulatory, and institutional problems, rather than any deficiency in the technology, is of little practical consequence. While we are seeing a daily improvement in economic indicators that gives us some hope of renewed investment, as yet that hope has not materialized. To dwell on our defeats, however, is counterproductive. We must now turn to new and alternative strategies for ensuring future nuclear vitality. With this challenge in mind, we have formulated the budget request that we are presenting to you today.

Our proposed programs are supportive of the President's nuclear policies and are entirely consistent with the Department's National Energy Policy Plan (NEPP-IV) sent to Congress last Fall. Our goal of ensuring that nuclear power remains a viable option for a balanced and diverse energy resource base contributes to the national goal of fostering an adequate supply of energy at reasonable costs. Important elements of this balanced system are new advanced technologies to provide adequate energy supplies well into the future. Our programs support the policy of minimizing Federal control and involvement in energy markets. Accordingly, all nuclear research and development will be conducted with an eye to transferring the technology to the private sector for demonstration and deployment as soon as is feasible.

We interpret our role as one of extending the nuclear technological horizon in order to create private sector opportunities for commercializing and marketing those concepts that best meet their needs. In addition, we must continue to fulfill the Federal responsibility for maintaining public health and safety and environmental quality in regard to all nuclear-related activities under our jurisdiction.

Madam Chairman, I would now like to highlight some of the major elements of our FY 1985 nuclear program.

Converter Reactors

In structuring our Converter Reactor Program for FY 1985 we have been keenly aware of the institutional problems that confront the current generation of commercial nuclear power--the light water reactor. The utilities are not committing capital for the construction of any large powerplants, be they nuclear or coal. Unless, and until the fundamental problems that result in unacceptable business risk for the utilities are resolved, there will be few, if any, orders for new, large powerplants of any kind. The consequence of this is higher than necessary electricity costs. For industries where electricity costs make up a substantial portion of their business expenses, such as the aluminum industry, this will result in a serious deterioration of their competitive position in the world market and/or the necessity to expand outside the United States with the attendant loss of jobs.

In some areas, utilities are turning to imports of Canadian nuclear electricity as a near-term expedient to reduce their supply costs. Unfortunately, these solutions reflect our inability as a Nation to solve the fundamental problems confronting the electric utility and nuclear industries today. The commercial nuclear power industry in the United States has taken over a quarter of a century and hundreds of billions of dollars to develop. The Nation must consider seriously the effects of the continued decline and ultimate demise of this industry.

We have analyzed carefully what steps the Federal Government could and should take to effect solutions that would renew confidence in the nuclear option. A priority emphasis will be on continued efforts to encourage passage of nuclear licensing reform legislation. The outdated system currently in use was established over 25 years ago. A more predictable process is badly needed to ensure efficient licensing and regulation of the plants already in operation or under construction. It is also a prerequisite to a renewed utility interest in nuclear investment.

On March 18, 1983, DOE sent to Congress its legislative proposal for improving the regulatory and licensing process for nuclear powerplants with the following three major objectives:

1) to provide for continued improvement in the safety of nuclear powerplants;

2) to improve the effectiveness of public participation; and

3) to provide a more stable and predictable licensing process.

The NRC also submitted a proposal for licensing and regulatory reform. It is important to note that the Administration's proposals are not an attempt to resolve the debate over the need for nuclear power or its desirability when compared with other energy sources. Nuclear licensing reform is a necessary but not sufficient condition for new nuclear powerplant orders. The proper role of nuclear power in the Nation's energy future should be decided by the free market system, but it cannot receive proper consideration if we continue with an inefficient and outmoded Federal regulatory process.

In addition to our effort to contribute to the resolution of problems confronting the nuclear industry, the Department will also be evaluating alternative, advanced design concepts. There is need to develop the technology for reactors that have less complicated safety systems and better economics, thereby increasing both public and utility confidence. We will also be evaluating the potential of small High Temperature Gas Reactors for unique domestic and international markets. Where appropriate, we will conduct collaborative programs with Japan and the Federal Republic of Germany. This is one of a number of areas in which we will be pursuing increased international cooperation in technology development.

The Converter Reactor Program also supports the cleanup at TMI. As you know, DOE has limited its effort to performing generic research and development that can contribute substantially to our knowledge both of accident recovery and accident prevention. We believe important technical progress is being made, but activity is impeded by a shortfall of required funds. The nuclear industry, through the Edison Electric Institute, pledged support for the cleanup with a target of $150 million. One hundred million dollars is required before funds can be transferred to General Public Utilities, the TMI owner. To date, only $80 million has been pledged but a recent favorable Internal Revenue Service ruling, which makes pledges tax deductible, is expected to generate additional funds. Although the DOE commitment to TMI cleanup remains firm, it now appears that our FY 1984 and 1985 expenditures will be less than planned due to slower than expected progress by the other parties involved in the effort.

Breeder Reactor Systems

Our FY 1985 request for Breeder Reactor Systems reflects the major restructuring that has taken place in the breeder program. While our overall goal remains the same--to develop the technology for introduction of a marketable breeder reactor by the private sector early in the next century--our strategy has changed. Last year our activities were project-oriented around Clinch River construction and operation. With the termination of Clinch River, our program focus has shifted to resolving those technical issues that stand in the way of commercialization by industry. We understand breeder technology; the United States still has the greatest technological base for breeders in the world, and we know it will work. The challenge now is to make it commercially viable. That can be done only if the cost of the product is brought in line with the cost of its competition and if it can be made attractive (i.e., safe and reliable) to both the customer and the public. And this challenge must be faced in light of new realities regarding Federal support for energy development. The Government simply will not finance future breeder demonstration powerplants. While the Federal Government will continue to be needed to provide certain institutional and financial support, large capital outlays are not practical or appropriate in the budgetary and political environment we face. Nor are they likely to be practical for some time to come.

The challenge then is to develop a breeder concept that can be built by the private sector on an economic basis, with the Federal Government playing a strong but limited role. In fact, during the past year, we have encouraged and supported industry to develop advanced reactor designs aimed at meeting sound economic, reliability, and safety criteria.

The Clinch River Project has produced valuable experience in the areas of design, component testing, and licensing. This information will be retained for use in the restructured base technology program. NRC's Atomic Safety and Licensing Board recently issued a memorandum of findings which resolved all issues in the CRBR Construction Permit hearings in favor of the Applicants. This decision, which would have been sufficient to authorize the issuance of a construction permit, confirms the technical merit of the CRBR Project. It also provides firm conclusions regarding the safety and environmental acceptability of breeder reactors and provides a benchmark for future breeder licensing effort. Clinch River Project close out activities are proceeding smoothly. An appropriation transfer of $40 million has been made from the Uranium Enrichment Program as an interim measure to fund CRBRP termination requirements. No new appropriations are expected to be requested in FY 1985.

The LMFBR research and development program in FY 1985 will be directed toward improving the technology for power conversion systems, components, instrumentation, and materials technology to the point where cost reduction and reliability potentials are realized. Continued operation of the breeder test facility complex at the Hanford Engineering Development Laboratory (HEDL) and the Energy Technology Engineering Center (ETEC) will provide the experience base and test capability for this effort.

The program will also assess advanced breeder concepts that offer the potential of improved economics and safety. These studies will include investigation of smaller-scale breeders, standardized designs, and reactors manufactured as a complete package or as modules in central fabrication facilities. They will be conducted with input from industry, the ultimate customer for breeders. Moreover, cooperative research with, and technology transfer to, the private sector will constitute an important element of development activity.

Another priority element of our program will be a substantial increase in international cooperative effort. We see significant benefits to be gained from the division of workload and the pooling of resources. We also anticipate that joint effort will encourage uniform or compatible safety standards, physical security measures, and safeguards.

In FY 1985, we will continue development of the breeder fuel cycle technology as well as confirmation of fuel breeding in a light water reactor using the uranium-233 fuel cycle. Our breeder fuel cycle program, however, will be conducted at a substantially lower level of effort. The lower funding recognizes the reduced requirements in both pace and extent for breeder fuel cycle technology development as a result of Clinch River termination. It is my personal belief that this is a period of reassessment and that circumstances will evolve that signal the need for more aggressive development of the breeder fuel cycle.

Advanced Nuclear Systems

Another important area of Departmental activity is the research and development of advanced nuclear systems in support of U.S. military and civilian space missions and other special applications. Work is divided into two major subprograms. The first is the Special Isotopic Power Sources Program. In FY 1985, flight systems development, production, and safety support will be conducted for isotopic power generators to be used in the Galileo and International Solar Polar spacecraft to be launched by NASA in 1986. Design efforts for an advanced modular generator to be used in space missions and for other special applications will be continued. A second program element is the Space Nuclear Reactor Program, which is a cooperative effort of the DOD, NASA, and DOE to examine several reactor concepts for potential use in future space missions.

Waste Technology

As you know, Madam Chairman, under the requirements of the Nuclear Waste Policy Act of 1982, the activities associated with the siting, construction, and operation of a national repository system for high-level nuclear waste were assigned to the newly established Office of Civilian Radioactive Waste Management. Prior to that, in 1980, legislation was enacted stating that the responsibility for disposal of low-level nuclear waste rests with the States. My role in nuclear waste management is to develop waste treatment technologies for the long-term management, storage, and disposal of civilian radioactive waste, be it low-level, high-level, or transuranic. In FY 1985, one of our activities will be to conduct safety and reliability tests on the ceramic melter system which is to be used to solidify high-level wastes. We will also continue to provide technical assistance to the States in their efforts to establish (either individually or by regional compacts) facilities for low-level waste disposal. In this regard, I am pleased to report that progress in forming compacts has been encouraging. To date, four compacts await Congressional approval and two more have been approved by the required number of States (four) in each region to permit submission to Congress.

Remedial Actions

Another important Federal responsibility in the management of nuclear wastes is our program for remedial actions at certain contaminated facilities and sites. This program is divided into four major subprograms. (1) The Formerly Utilized Site Remedial Action Program (FUSRAP) covers former nuclear processing sites that require stabilization or removal of contaminated material. DOE currently has authority for conducting remedial action at 19 sites. In FY 1985, remedial action will be completed at the Niagara Falls Storage Site in New York and work will continue at other sites for which DOE has authority. (2) The Uranium Mill Tailings Remedial Action Program (UMTRAP) is directed toward the cleanup of 24 inactive uranium mill tailings disposal sites and several thousand associated vicinity properties. In FY 1985, cleanup will be completed at the Canonsburg, Pennsylvania, site and about one-third of the necessary work at the Salt Lake City, Utah, site and two-thirds at the Shiprock, New Mexico, site will be completed; (3) A third program covers our participation in a Federal/State cooperative effort to remove uranium mill tailings used for construction purposes in Grand Junction, Colorado. By the end of FY 1985, we will have completed remedial actions at 623 of the 626 structures requiring attention. (4) The Surplus Facilities Program provides for the safe management and disposition of contaminated DOE civilian program facilities (currently grouped into about 55 projects) that are no longer in use. In FY 1985, dismantlement of the Shippingport Atomic Power Station will be initiated, which will demonstrate the safe and economical cleanup of a commercial power reactor.

Yet another waste management activity for which we have responsibility is the demonstration of high-level waste solidification at the Western New York Nuclear Center near West Valley. In FY 1985, the West Valley Program will focus on vitrification testing, engineering, and procurement of waste solidification support systems and decontamination and decommissioning of the facility.

Uranium Enrichment

I have saved discussion of one of the Department's business enterprises--the Uranium Enrichment Program--for last. The problems I reported to you a year ago--a worldwide excess of enriched uranium, increasing competition from foreign enrichment suppliers, and the emergence of the secondary market--are still with us. Today the U.S. share of the global enrichment market has dropped significantly from the monopoly it held 10 years ago. Customers, understandably, are attracted to suppliers that can offer lower prices and more flexible contract terms for their enrichment services. Decreased demand, DOE's outmoded business practices and the drastic change in currency exchange rates no longer allow us to be a competitive supplier.

Over the past year we have analyzed the situation carefully, considered alternative options, and developed a strategy that we believe will significantly improve the U.S. market position. Our most pressing needs are to stabilize our market share, provide an orderly work-off of excess inventories, and stem the tide of customers who are going elsewhere for their enriched uranium. Consequently, the first element of our strategy was to offer a new contract with terms sufficiently attractive to interest potential customers and to retain our present customers. This step was taken on January 18 with the issuance of the Utility Services contract. The new contract offers several competitive features including a reduced price with a long-term price ceiling, the ability to purchase a portion of requirements from foreign suppliers or the secondary market, and ordering and delivery provisions that are substantially more flexible.

The second element of our strategy is to plan and conduct the activities in all areas of the uranium enrichment enterprise in a more efficient and cost effective manner. With regard to existing production capacity, we are making vigorous attempts to obtain relief from the TVA demand charges for power and to introduce more effective cost control measures into our gaseous diffusion operations. As market data are obtained from customer response to the new contract, we can adjust our program scope and outlays in proportion to our revenues.

The market response to our new contract will also determine future investment in new capacity and in research and development. An important element of our long range strategy is to replace the gaseous diffusion operations with technologies that are more energy efficient and, ultimately, more cost effective. As you know, we are currently building a Gas Centrifuge Enrichment Plant (GCEP) at Portsmouth, Ohio. Our plan is to proceed in FY 1985 with construction of GCEP buildings 1 and 2 and procurement of Set III centrifuges. No funds are committed to any additional buildings at this time.

We are developing advanced gas centrifuge (Set V) and the Atomic Vapor Laser Isotope Separation technologies. In the near term we plan to continue R&D on both. In FY 1985, we plan to select one of these advanced technologies for further development.

Success in our new enrichment strategy will affect a number of important national considerations. It will enable our domestic utilities to have a reliable indigenous supply of fuel. It will ensure that our defense requirements are met. And by meeting the needs of foreign nations it will further our nonproliferation objectives.

In summary, Madam Chairman, the nuclear programs we are describing today differ markedly from those of the past. We have acknowledged the realities of the marketplace and have introduced modern principles of good business into our programs. In recognition of the constraints of the current national fiscal policy we have set strict priorities for sharply focused activity. And, we have a clearer delineation of government/industry responsibilities. One thing that has not changed, however, is our belief in a strong nuclear option and our commitment to strive for its realization. We look forward to working with this and other committees of Congress in achieving this objective.

I would now like to describe in some detail the Department's nuclear programs.

CONVERTER REACTOR SYSTEMS

The FY 1985 budget request for Converter Reactor Systems is $83.5 million, a decrease of $9.2 million from the FY 1984 appropriation. The distribution of funds is as follows:

	FY 1984	(in millions)	FY 1985
Light Water Reactor Systems	$ 19.5		$ 16.0
High Temperature Reactors	30.0		34.6
Advanced Reactor Systems	5.0		0.0
Three Mile Island Activities	37.0		32.2
Program Direction	1.2		0.7
Total	$ 92.7		$ 83.5

The overall goals of the Converter Reactor Systems Program are: 1) to improve the economic and safe use of nuclear reactors; 2) to contribute to the resolution of the nuclear industry's regulatory, financial, and institutional problems and 3) to fulfill the Federal Government's research and development commitment associated with General Public Utilities' cleanup of Three Mile Island (TMI).

LIGHT WATER REACTOR SYSTEMS

The Advanced Reactor Evaluations element of our program will focus on safety in improved advanced converter reactors. While the current LWR industry has an outstanding safety record, there are improvements that may be made to any technology. The basic question of how changes in the current size and design of commercial converter reactors could improve safety (both real and perceived), and better meet the utility needs, will be addressed by this program.

The Department will continue to fulfill its role of reviewing and reporting to Congress on the national research and development programs conducted by both private sector and government organizations, as required under P.L. 96-567.

We will also continue participation in the Loss-of-Fluid Test (LOFT) Program, an internationally funded activity under the auspices of the Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development (OECD). This consortium selected a test program to be carried out over a three year period beginning in FY 1983. During that year, three thermal-hydraulic tests were successfully performed within budget and ahead of schedule. In FY 1984, the final three thermal-hydraulic tests will be completed and preparations will be made for two fission-product release and transport tests. These fission product tests, to be performed in FY 1985, will provide important data relevant to the magnitude of the radioactive source-term, which is a significant input to the technical basis underlying many nuclear licensing and regulatory requirements. By early FY 1987, all analysis should be completed and the LOFT reactor deactivated and decontaminated.

The original total LOFT program cost estimate was $93.5 million. Of this, NRC provided $25 million in FY 1983, DOE is providing $45 million in increments of $15 million in FY 1984, 1985, and 1986, the Electric Power Research Institute is contributing $1.5 million, and foreign countries are expected to contribute $22 million.

HIGH TEMPERATURE REACTORS

Following completion in FY 1984 of activities related to the design of a proposed large high temperature gas-cooled reactor (HTGR), efforts in FY 1985 will be refocused to evaluate the potential of small HTGRs for unique domestic and international markets. In addition, the development of the technology base needed for HTGR electric and process heat applications will be supported. These activities and objectives are consistent with the current policy of support for long lead time, high technology advanced concepts that cannot be fully supported by the private sector.

The primary thrust of this program will be to evaluate and develop the potential of small gas reactors for multiple applications. Technical and economic design assessments will be performed to guide the base technology development activities and the selection of a reference small reactor concept. The technical approach is to utilize the inherent lower power density of small HTGRs to minimize the need for engineered safety features. The evaluation and development of the HTGR concept will be closely coordinated with appropriate user groups to assure evolving marketplace compatibility. Alternative market, business, and financial strategies will be developed by the users consistent with their needs and requirements in order to guide the evaluation of the small HTGR and the configuration of the HTGR which best meets the needs of the market.

The HTGR program will also emphasize the advancement of the technology base needed to support the development of small, gas-cooled reactor systems with less complex safety systems. Additionally, technology activities will be performed to address many of the technical design safety issues that have been identified from the operational experience gained at Fort St. Vrain, from changes in nuclear regulation, and from changes in user (utility) requirements.

ADVANCED REACTOR SYSTEMS

In FY 1984, efforts have continued on irradiation testing of candidate replacement low enriched uranium (LEU) fuel systems and fabrication development to qualify commercial sources of these alternative fuels. In FY 1985, funding for this program is not being requested by the Department of Energy; however, the Arms Control and Disarmament Agency has requested funding to support this activity in FY 1985.

THREE MILE ISLAND ACTIVITIES

The Three Mile Island (TMI) program is budgeted under the Converter Reactor program but is managed under the Office of Terminal Waste Disposal and Remedial Action, and is discussed under that section of this statement.

BREEDER REACTOR SYSTEMS

The Breeder Reactor Systems budget request for FY 1985 is $308.1 million, a decrease of $115.1 million from the FY 1984 appropriation. Distribution of the funds is as follows:

	FY 1984	FY 1985
	(in millions)	
Clinch River Breeder Reactor Plant (Termination)	\$ 40.0[1/]	\$ 0
Liquid Metal Fast Breeder Reactor	300.8	261.6
Nuclear Fuel Cycle	35.4	11.9
Water Cooled Breeder	35.5	26.3
Program Direction	11.5	8.3
Total	\$423.2	\$308.1

1/ An Appropriation Transfer of \$40.0 million has been made from Uranium Enrichment as an emergency interim measure to fund immediate CRBRP termination requirements.

LIQUID METAL FAST BREEDER REACTOR PROGRAM

The Liquid Metal Fast Breeder Reactor (LMFBR) program has been restructured to focus on resolving those technology issues that are key to improved breeder economics and predictable, safe performance. The revised program will be fully consistent with our National energy research and development policy in that there will be no new Federally funded demonstration projects. The responsibility for demonstration of breeder reactor technology, including definition of program scope, timing, funding arrangements, and management, resides with the private sector. The Federal program for FY 1985 complements industry efforts by emphasizing:

o Technology research and development necessary for a breeder system that has less complicated safety systems, is reliable, is competitive with alternatives, and meets the market needs of utilities;

o Development of advanced plant concepts;

o Major, substantial international collaboration; and

o Development of LMFBR fuel cycle technology.

A major effort will be directed toward advancing the technology for power conversion systems, components, instrumentation, and materials technology, as well as for the related fuel supply system, to the point where cost reduction and reliability potentials are realized. Testing of breeder systems, fuels, components, instruments, and materials takes place at the Hanford Engineering Development Laboratory (HEDL), the Energy Technology Engineering Center (ETEC), and the Argonne National Laboratory (ANL).

Recent studies indicate that advanced breeder concepts can be economically competitive with alternatives (e.g., LWR's and coal plants) and deployed with relatively short lead times in sizes matched to various grid requirements. The feasibility of these advanced breeder concepts will be assessed with input from the user industry, the ultimate customer for breeders. Explicit attention will be given to the potential advantages of smaller reactors of standardized design that are capable of being replicated in total (or by module) in central fabrication facilities. Smaller-sized fuel cycle facilities also have attractive economies to match plant sizes. Cooperative research with, and technology transfer to, the private sector will constitute an important element of the reoriented breeder program.

A major thrust of the FY 1985 program will be the emphasis on international collaboration in breeder technology to reduce U.S. program costs and to retain the U.S. role in international nuclear forums. The experience gained in design, component testing, licensing, and analysis from the CRBRP project as well as our advanced breeder knowledge acquired from the operation of the Fast Flux Test Facility (FFTF) and the base program will be valuable in establishing exchange agreements with other nations.

A smaller-scale effort, the Water-Cooled Breeder program, is devoted to proving breeding can be achieved in a light water reactor using the uranium-233/thorium fuel system. Efforts in FY 1985 will continue the defueling activities and core evaluation of the light water breeder core from the Shippingport Atomic Power Station.

Clinch River Breeder Reactor Plant Project

There were no funds appropriated to continue the Clinch River Project in FY 1984. Therefore, on November 10, 1983, the parties involved--the Department of Energy (DOE), Tennessee Valley Authority (TVA), Commonwealth Edison, Project Management Corporation (PMC), and Breeder Reactor Corporation (BRC)--agreed to terminate the project, effective November 14, 1983. The agreement was formalized on December 19, 1983.

Termination activities began in early FY 1984, and are planned for completion in early FY 1985. These include the termination and/or relocation of project personnel; termination of contracts and subcontracts; site redress work; settlement of terminated contracts and subcontracts; documentation of certain completed work; completion of selected computer verification efforts that were approaching completion when the project was terminated; arrangement for retention and appropriate availability of scientific and technical information generated under the project; storage, maintenance, relocation of CRBRP components, equipment, materials, etc., for use within the LMFBR program and other Government programs, as appropriate; and disposition of inventories not of value to the LMFBR program.

Large Scale Prototype Breeder

The Government sponsored design efforts on a Large Scale Prototype Breeder (LSPB) plant will be phased out in an orderly manner during FY 1984. The program has been a joint effort of the U.S. Government and private industry to develop a large scale prototypical breeder demonstration plant. The plant was to have been the logical follow-on to the Clinch River Project as a full-scale demonstration plant. The LSPB design will be maintained as a frame of reference for benchmarking advanced concepts developed under the base program.

LMFBR Base Program

The mission of the LMFBR base program is to develop the requisite technology to the point where the private sector is able to construct and operate safe, reliable liquid metal fast breeder reactor plants for supplying electricity to the grid. This includes studies of the technical features applicable to future private sector initiatives. The program has been reoriented to place primary emphasis on designing less complicated safety systems and achieving economic competitiveness in future advanced concepts. It is to this end that the breeder technology and test facilities efforts discussed in the following paragraphs are directed.

Concepts and Requirements Development--An effort will be initiated to identify plant concepts that could be developed by industry for use in the marketplace and to assess unique market needs that can be satisfied by the breeder technology program.

During FY 1985, development efforts on the advanced concept studies will be conducted by contractors selected during FY 1984 as part of a competitive procurement process. This effort will include development of plant requirements and safety criteria; safety analyses; licensing assessments; seismic evaluation; constructability assessment; identification of R&D requirements; and analysis of cost and schedule potential. Market analysis will be conducted to assure proper program and concept development. The studies will utilize to the maximum extent possible previously developed technology and information gained under the current international collaborations, including the DOE/ Japanese MONJU agreement. R&D requirements will be constantly coordinated with other parts of the base program.

Beginning in FY 1984 and during FY 1985, an information exchange will be conducted with the Nuclear Regulatory Commission (NRC) aimed at developing licensing criteria for future advanced LMFBR's. Key LMFBR issues will be identified and used as a basis for improving the licensability of LMFBR's and contributing to an efficient licensing process.

Power Conversion Technology--It is essential that major cost reduction and reliability potentials are realized in order to justify investor and public acceptance to build and operate economically competitive liquid metal reactors. The Power Conversion Technology Program focuses on these potentials and encompasses the power conversion systems and the components necessary to convert heat to electricity. Standardized plants and more cost effective methods for achieving quality assurance are two concepts of special interest for accomplishing the reduced costs and reliability goals.

The research and development to improve the performance predictability and reliability of power conversion components includes flow induced vibration analysis, flow distribution testing and analysis, mixing and stratification testing and analysis, subcomponent development and testing, fabrication process development, inspection development, and procedure development. Efforts are underway to develop data on materials properties, including fabrication and environmental effects. Documentation of these data in handbook form will serve as an authoritative source for use in the design and licensing processes. The program also includes the development of a new ferritic alloy which offers significant economic and engineering advantages over current reference structural alloys.

Significant accomplishments for FY 1984 include: successful completion of sodium testing of the 35,000 GPM pump which disclosed needed modifications that would not otherwise have been discovered; successful completion of sodium testing of the hockey stick steam generator in both the recirculation and once-through modes; and successful completion of water testing of the 85,000 GPM two stage primary pump preparatory to shipping all pump system parts to ETEC by the end of 1984.

Specific accomplishments planned for FY 1985 include: continue preparation for sodium testing of the helical coil model steam generator; develop a

14,000 GPM electromagnetic primary sodium pump for modular reactor applications; and initiate balance-of-plant cost reduction, simplification, and standardization studies. Fabrication of the 70 MWt double-wall tube steam generator will continue, with delivery in FY 1986. Development of this component has the long-term potential for eliminating the intermediate sodium system and avoiding the need for a sodium water reaction product separation system.

Fuel Performance and Supply--The Fuel Performance and Supply program's objectives include proving the performance of fuel, blanket and absorber core components under prototypic operating conditions and demonstrating safe, reliable, and licensable core systems. Specific objectives include extending the lifetime of core components to a minimum of 3 years; automating fuel fabrication to achieve competitive fabrication costs; improving safeguards and reducing personnel exposure; and transferring developed technology to industry.

The development of carbide and metal fuels for advanced and smaller sized plants will proceed because of the potential advantages in smaller control requirements, smaller sizes, and lower fuel cycle costs that these fuel systems offer. International participation in the Core Systems and Materials Program will continue to reduce program costs while maximizing technological benefits.

In the Fuel Supply area, activities will continue toward completing the Secure Automated Fabrication (SAF) line. Procurement of equipment and its installation in the Fuels and Materials Engineering Facility (FMEF) will continue. Upon its completion and operation in the late 1980's, the SAF line will demonstrate breeder fuel fabrication technology that can be deployed commercially by industry. Activities for fuel assembly capability in the FMEF will be initiated in FY 1985.

Nuclear Systems Technology--The disciplines of safety, physics, structures, thermal hydraulics, and reactor core design are integrated into a single, cohesive unit in the Nuclear Systems Technology program. The program will focus on experimental verification, in existing DOE facilities, of the feasibility of advanced reactor concepts of varied design, size, and fuel type that exhibit self-terminating capability under failure conditions. All functions needed to assure nuclear safety under abnormal conditions are integrated into the nuclear systems. Demonstration of inherently safe nuclear systems operations will reduce the requirements for supporting auxilliary equipment whose purpose is to control otherwise dangerous conditions. Such support equipment substantially increases the complexity of design. These studies will enable the development of a reliable advanced technology that is competitive and compatible with user needs and capability.

Varied fuel types (metal, oxide, carbide) and fuel pin sizes will be evaluated, as well as the effects of varied core designs on voiding, temperature, and reactivity coefficients. Features supporting inherently safe operation will be developed, reflecting the redirection in the safety program which places more emphasis on the existing safety features of breeders and less on breeding ratios and other plant parameters.

Work will continue in support of upgrading the TREAT reactor to provide the principal in-reactor safety phenomena testing capability. Also, a program of operational safety experiments on integrated systems will be conducted at the EBR-II reactor facility.

Test Facilities--The test facilities effort consists of operating and maintaining facilities at the Hanford Engineering Development Laboratory (HEDL), the Energy Technology Engineering Center (ETEC), and the Argonne National Laboratory (ANL) to conduct LMFBR program test requirements. In addition, the Los Alamos National Laboratory (LANL) conducts nuclear related studies and assessments in support of the program.

HEDL Facilities

The Hanford Engineering Development Laboratory (HEDL), which is operated by Westinghouse Hanford Company in Richland, Washington, plays a key role in breeder reactor development and testing activities. The major test facility at HEDL is the Fast Flux Test Facility (FFTF) which provides a test bed for demonstrating and evaluating the performance of breeder reactor fuel assemblies and partial core loadings at reference conditions. Efforts will focus on operation of the FFTF and the installation of the Secure Automated Fabrication line equipment.

Facilities operated at the HEDL site include:

o The Fast Flux Test Facility (FFTF), a 400 MWt liquid metal (sodium) cooled fast-neutron-flux loop type reactor designed specifically for irradiation testing of nuclear reactor fuels and materials for fast breeder reactors.

The performance of the FFTF during 1983 and 1984 is particularly noteworthy; three full cycles of operation were completed and preparation for a fourth is now underway; the reactor was operated for a nominal 100 days during each cycle and, in the third cycle, experienced 55 days continuous full power operation without interruption. The performance of the fuel subsystem exceeded its design goal burnup of 85,000 megawatt days per tonne during the third cycle without failures.

- The Fuel Storage Facility, located adjacent to the FFTF, is used to store and remove decay heat from irradiated FFTF fuel and reactor experiments.

ETEC

The Energy Technology Engineering Center (ETEC), which is located 40 miles northwest of Los Angeles and is operated by Rockwell International, is the breeder program's nonnuclear component testing center. ETEC has several large on-site nonnuclear sodium testing facilities with the unique capability to test fast breeder reactor components under all operating conditions. Some smaller ETEC facilities will accomplish testing on selected small reactor plant components, instrumentation and subsystems. Efforts will continue toward realizing innovative methods for economical long term steam generator testing.

ANL Facilities

The Argonne National Laboratory (ANL) efforts are primarily accomplished at the ANL-West (ANL-W) site at the Idaho National Engineering Laboratory. These activities include plant and component operating experience in addition to specific testing efforts in support of fuel performance and nuclear systems technology. Development of innovative methods to achieve economical long term testing of key components such as pumps, steam generators, and inherent safety features is a continuous effort in parallel with testing activities.

Facilities that are operated at the ANL-West site include:

- The Experimental Breeder Reactor-II (EBR-II)
- The Hot Fuel Examination Facility (HFEF)
- The Zero Power Plutonium Reactor (ZPPR)
- The TREAT (transient test) Reactor

LANL

The Los Alamos National Laboratory (LANL) efforts are primarily general program and nuclear studies and assessments, and nuclear training activity.

Initiatives in support of cost-effective operations are being implemented throughout the test facilities complex. Cost and schedule controls ensure economic and efficient use of the test facilities; consolidation of testing and demonstration activities is continuously under review. Facilities surplus to base program needs will be phased out.

NUCLEAR FUEL CYCLE

The fuel cycle activities include development of advanced technology for reprocessing of irradiated fuels from nuclear power reactors with emphasis on the more stringent requirements associated with reprocessing breeder reactor fuel. These include higher thermal and radiation burdens, higher fissile content, sodium contamination, and more complex fuel assembly structures. The technical program is focused on development of technology that will provide smaller-scale facilities for equivalent throughput, reduced radiation exposure to workers, increased environmental protection, increased reliability, enhanced safeguards, and reduced costs.

In FY 1984, design, fabrication, and testing of advanced smaller size, higher throughput equipment in the Integrated Equipment Test (IET) facility at Oak Ridge will continue to evaluate performance and remote maintenance concepts. Specific items to be tested include fuel disassembly and shear systems, a continuous rotary dissolver, centrifugal contactors for solvent extraction, and an advanced servomanipulator needed for remote operations and maintenance.

In FY 1985, remotely operable and maintainable reprocessing equipment and systems will be developed and some integrated cold testing in the Integrated Equipment Test Facility will be conducted. Laboratory and hot cell experiments on flow sheet development will continue at a reduced level. Efforts in FY 1985 will also include providing supporting analysis and evaluation for the light water breeder reactor proof-of-breeding demonstration, and evaluation of methods and cask designs for handling and shipping irradiated breeder fuel.

WATER COOLED BREEDER

The Water Cooled Breeder program's mission is to develop technology for significantly improving the efficiency of nuclear fuel resource utilization by light water reactors used for electrical power generation. The objective is to accomplish the following: prove that breeding can be achieved in a light water nuclear reactor using the uranium-233/thorium fuel system; confirm a practical way to use thorium (a plentiful source of fuel for which there has been no major energy-related use); show the feasibility of installing prebreeder and breeder cores of the light water breeder reactor type in existing and future pressurized water reactor plants using current types of plant components and systems; and make the technology developed under the program available to industry.

A light water breeder core was installed in the Shippingport Atomic Power Station in 1977. On October 1, 1982, the Shippingport Station ceased power operations; end-of-life testing was performed and defueling of the light water breeder reactor core was begun.

Core removal operations are scheduled to be completed by the end of FY 1984. Major activities in FY 1985 will include: completing documentation of core removal operations; preparating for long term storage of expended fuel; and shipping of spare and physics fuel rods to storage.

Core evaluation work in FY 1985 will include: disassembling light water breeder core fuel modules for examination and storage; providing facilities and equipment for light water breeder fuel module examination and assay; preparing fuel rods for nondestructive assay; performing of proof-of-breeding work; analyzing effects of extended core operation on core materials; and continuing thermal and hydraulic analysis of light water breeder reactor components.

ADVANCED NUCLEAR SYSTEMS

The Advanced Nuclear Systems budget request for FY 1985 is $33.5 million, a decrease of $0.6 million from the FY 1984 appropriation. Distribution of the funds is as follows:

	FY 1984	FY 1985
	(in millions)	
Special Isotopic Power Sources	$ 27.7	$ 28.0
Advanced Systems Evaluation (Space Nuclear Reactor)	5.0	4.5
Program Direction	1.4	1.0
Total	$ 34.1	$ 33.5

The goal of the Advanced Nuclear Systems program is to develop and deliver specialized nuclear power sources for U.S. military and civilian space missions and other special applications. Activity is conducted within two program elements: the Special Isotopic Power Sources program and the Space Nuclear Reactor program. The latter is a tri-agency cooperative endeavor of DOD, NASA, and DOE.

The Advanced Nuclear Systems Program supports civilian and military space applications through the development of a range of nuclear power system options. A number of developed nuclear isotopic power sources are used by the Department of Defense and the National Aeronautics and Space Administration; operating data from these systems are being reviewed. For example, Pioneer 10 launched in 1972 and Pioneer 11 launched in 1973, continue to transmit telemetry data which indicate that the space isotope power supplies are operating as designed. In addition, the DOD Lincoln Experimental Satellites 8/9 (in orbit since 1976) and the NASA Voyager 1 and 2 spacecraft (launched in 1977) continue to obtain their total spacecraft power needs from their onboard isotope generator.

The current generation of Radioisotope Thermoelectric Generators (RTGs) under development will deploy the General Purpose Heat Source (GPHS) for the NASA

Galileo and International Solar Polar Missions planned to be shuttle launched in 1986. Each GPHS RTG weighs 123 pounds and produces about 285 electrical watts.

SPECIAL ISOTOPIC POWER SOURCES

The FY 1985 isotope power development program has three major activities. First, the readiness and shipment of the GPHS RTG flight units to be used in the silicon germanium generator for the NASA Galileo and the International Solar Polar Missions. The second effort is the development of a new modular RTG concept that offers the potential for a more advanced, much lighter generator, i.e., high specific power to weight ratio, for future space missions. During FY 1985, ground demonstration system (GDS) fabrication and assembly will be accomplished. The third activity involves RTG development for special military applications. In FY 1985 emphasis will be on the GDS fabrication, completion of final design definition, and the safety evaluation of the RTG.

ADVANCED SYSTEMS EVALUATION (SPACE NUCLEAR REACTOR)

The Space Reactor Development Program and the Space Power Advanced Reactor Program were consolidated to form the Space Nuclear Reactor (SP-100) program to support a Memorandum of Agreement which was signed on February 11, 1983, by the Defense Advanced Research Projects Agency (DOD), the Office of Aeronautics and Space Technology (NASA), and the Office of Nuclear Energy (DOE). The agreement establishes the relative responsibilities of the three agencies during the conceptual development phase of the program. In FY 1984, several reactor system concepts are being examined to determine which concept would enhance or enable future civil and military space missions. Long lead efforts in technology development and related tasks began in 1983 and will continue through 1985. A key decision is planned during FY 1985 on whether to proceed with a ground engineering prototype demonstration. If a decision is made to proceed to a prototype, substantial increases in funding will be necessary in FY 1986 and beyond for the ground engineering test, for associated facilities improvements at a DOE laboratory or contractor location, and for the transition of the program into more detailed design and development activities.

The current multi-agency agreement expires at about the end of FY 1985. A new agreement will be necessary if a decision is made to proceed to the SP-100 Ground Engineering Test Phase (FY 1986-1989). Upon selection of a specific system for the final development, the management structure will be changed to a more traditional line structure with separate activities and clearly defined interfaces for each agency. DOE will be responsible for developing the nuclear subsystem during this phase.

During FY 1985, several reactor development system contractors will be funded in order to develop reactor conceptual designs for space systems applications. Conceptual designs will be developed and a baseline, backup, and growth design will be completed. System and nuclear safety program activities are to be continued in preparation for potential ground engineering systems tests scheduled for FY 1986.

REMEDIAL ACTION PROGRAM

The FY 1985 budget request for the Remedial Action Program is $152.0 million, an increase of $53.0 million over the FY 1984 appropriation. The distribution of funds among the program elements is as follows:

	FY 1984	FY 1985
	(in millions)	
Formerly Utilized Sites	$ 17.0	$ 16.0
Grand Junction	1.5	1.5
Uranium Mill Tailings	27.9	54.0
Surplus Facilities	15.5	30.0
West Valley	36.0	49.4
Program Direction	1.1	1.1
Total	$ 99.0	$152.0

The objective of the Remedial Action program is to treat or stabilize radioactive wastes and perform required decontamination and decommissioning at contaminated DOE and at legislatively authorized non-government facilities and sites. The major activities are: (1) the Formerly Utilized Sites Remedial Action Program (FUSRAP); (2) remedial action at Grand Junction, Colorado (P.L. 92-314, as amended); (3) the Uranium Mill Tailings Remedial Action Program (UMTRAP) for inactive uranium mill tailings sites (P.L. 95-604); (4) management of certain radioactively contaminated Department facilities declared surplus and resulting principally from civilian nuclear energy programs; and (5) demonstration of the solidification of high-level radioactive wastes at West Valley for final disposal (P.L. 96-368).

FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM

The Formerly Utilized Sites Remedial Action Program (FUSRAP) provides for remedial actions at former nuclear processing facilities, most privately owned, which became radioactively contaminated from Manhattan Engineer District or Atomic Energy Commission activities and which have not been decontaminated sufficiently to meet current health effects guidelines. To remedy the situation, the contamination will be either stabilized in-place, with restrictions placed on site use, or the contamination will be removed and disposed of at another location. Authority derived from the Atomic Energy Act of 1954, as amended, currently exists for conducting remedial actions at 15 sites. This authority is based on our review of the involvement of agency predecessors in activities at these sites. Review of other sites involved in past activities of the agency's predecessors is continuing and may result in the addition of sites to the program. Congress added four new sites and $5.0 million in the FY 1984 Energy and Water Development Appropriations Act with direction to initiate, as a priority action, a decontamination research and development project at these sites and vicinity properties, bringing the program site total to 19. The Department's Oak Ridge Operations Office has the lead for implementing the program.

In FY 1984, we expect to complete much of the cleanup work for contaminated properties near the DOE-owned Niagara Falls Storage Site at Lewiston, New York. Other remedial actions on this site will be described in my testimony on the Surplus Facilities Program. We are also planning to complete remedial actions at the Middlesex Landfill, New Jersey, and at the University of Chicago, Illinois. Material contaminated with uranium will be excavated from the Middlesex Landfill and temporarily stored at the nearby DOE-owned Middlesex Sampling Plant. At the University of Chicago, about 600 cubic feet of contamination in several laboratories will be removed and sent to the DOE disposal site at Hanford, Washington.

Preparations are underway to begin decontamination actions at the Maywood, New Jersey; Wayne/Pequannock, New Jersey; Colonie, New York; and Hazelwood, Missouri, sites which were added to the program in FY 1984. Cleanup of residential properties at Maywood and Wayne/Pequannock is scheduled to begin March 1984, at Colonie in May 1984, at Hazelwood in July 1984. Our general approach to these projects is to give priority to cleanup of contaminated vicinity properties and to store the waste temporarily on each processing site. We also will take steps to prevent any further offsite contamination from these four sites. For the longer term, the Congressional direction is to decontaminate these sites. Because of the large volumes of waste involved, we have asked each of the three states in which the waste is located to designate a site for disposal within the state. DOE would then proceed to acquire the site and effect disposal. These actions are expected to require more than 10 years to complete at total costs exceeding $100 million. Due to the large quantities of material and the large costs associated with relocation, we will examine from the technical, environmental, and economic viewpoints, the alternative of stabilizing the wastes at their present locations for two of the sites, Maywood and Colonie, and report the results to Congress.

Other survey, preliminary engineering, and environmental review activities are underway for the Albany Research Center at Albany, Oregon, the DuPont plant at Deepwater, New Jersey, and the Middlesex Sampling Plant at Middlesex, New Jersey. We are also continuing monitoring of the Palos Park site in Illinois and the St. Louis Airport Storage Site in Missouri.

In FY 1985 the cleanup of contaminated properties near the Niagara Falls Storage Site at Lewiston, New York, will be completed. We will continue the priority decontamination projects at Maywood, Wayne/Pequannock, Colonie, and

Hazelwood. Cleanup of the residential properties in Maywood, the adjacent properties in Rochelle Park and Colonie, and Latty Avenue in Hazelwood will be completed and work will start on other vicinity properties. Design engineering and environmental analysis will be completed for the Albany, Oregon, site.

GRAND JUNCTION REMEDIAL ACTION PROGRAM

Under Title II of Public Law 92-314, Congress authorized financial assistance to the State of Colorado to limit radiation exposure resulting from the use of uranium mill tailings for construction purposes in Grand Junction, Colorado. This State/Federal cooperative effort with the State of Colorado is administered by the Colorado Department of Health through the Grand Junction Area Office. The remedial action provides for removal of uranium mill tailings from the premises of about 626 structures where radon daughter exposures exceed the Surgeon General's guidelines. Public Law 95-236 extended the time for property owners to apply for inclusion in the program, which has now expired, and increased authorized program funding. Federal funds cover 75 percent of the program costs with the State providing the balance. FY 1986 is expected to be the last year Federal funds will be requested for the program.

Through FY 1983, work had been undertaken on 543 structures. In FY 1984 the program will continue with radiological assessments and will initiate remedial actions at about 50 structures. In FY 1985, the program will complete remedial actions on these 50 structures and will initiate and complete remedial action on 30 additional structures for a total of 623 structures out of the 626 to be completed.

URANIUM MILL TAILINGS REMEDIAL ACTION PROGRAM

The Uranium Mill Tailings Remedial Action Program (UMTRAP) is responsible for conducting remedial actions at 24 former processing sites and several thousand contaminated vicinity properties as mandated by Public Law 95-604, "The Uranium Mill Tailings Radiation Control Act of 1978." Nine of the sites are designated as high priority, six as medium priority, and nine as low priority. The Act requires completion of the program within 7 years of the March 1983 promulgation of standards by the Environmental Protection Agency. Based on the results of an evaluation to assess the feasibility and budget impact of the mandated 7-year schedule, the Department has concluded that this schedule can be maintained. Project implementation is proceeding under baseline cost and schedule estimates that are consistent with the March 1990 completion date. The current strategy is to focus near-term program activities on the higher priority sites and vicinity properties. Remedial actions are being conducted in accordance with cooperative agreements negotiated with the affected States and Indian tribes. Federal funds cover 90 percent of the remedial action costs (100 percent for those sites on Indian lands). The type of remedial action for the processing sites will be either to stabilize the mill tailings in-place, where feasible, or to remove the tailings to a new federally-owned disposal site. Engineering plans and environmental documents will be prepared for the cleanup and disposal operations at each site. The concurrences of the Nuclear Regulatory Commission (NRC) and the affected State or Tribe are required for each site remedial action plan. The program also includes the cleanup of contaminated vicinity properties. It is estimated that from 5,000-6,000 vicinity properties, mainly in the Grand

Junction area but not covered by the Grand Junction program, may be found eligible for cleanup. The Albuquerque Operations Office has the lead role in implementing this program.

Specific accomplishments planned for the balance of FY 1984 include the continuation of remedial action at Canonsburg, Pennsylvania, and initiation of remedial action at Salt Lake City, Utah. The Salt Lake City schedule has been adjusted to reflect the plans to relocate the tailings to a site near Clive, Utah. Cleanup also will continue at high priority vicinity properties near the Canonsburg, Salt Lake City, and Grand Junction, sites, and will be started at Edgemont, South Dakota, and Durango, Colorado. Remedial action plans will be completed, with State/Tribe and NRC concurrences, for Shiprock, New Mexico, and Gunnison, Colorado, and will be initiated for Durango, Colorado; Riverton, Wyoming; Lakeview, Oregon; Tuba City, Arizona; and Mexican Hat, Utah.

During FY 1985 the work on the Canonsburg processing site and on the remainder of the 125 vicinity properties will be completed. The work at Salt Lake City will be brought to 30 percent completion and remedial action will start at Shiprock and be 60 percent completed. Onsite work also will be started at Durango. Approximately 215 vicinity properties, located at several high priority sites, will be cleaned up.

SURPLUS FACILITIES PROGRAM

This program provides for the safe management and disposition of the inventory of surplus radioactively contaminated Department-owned facilities from civilian nuclear energy development programs. The decontaminated facilities and sites are returned to other productive use where appropriate. All defense-related facilities are included in the Defense Nuclear Waste Management Budget. The facilities are grouped into about 55 projects under this activity. In addition, the program develops improved methods for decontamination and decommissioning which can be transferred to industry. A long range plan will be completed by the end of FY 1984 to establish the overall schedule and priorities for sites currently in the surplus inventory. Priorities are established and work schedules are developed through analysis of legal, economic, and health/safety factors for each site. The Richland Operations Office has the lead field office role in implementing the program.

In FY 1984, the major onsite cleanup and upgrading of storage facilities will be completed at the Niagara Falls Storage Site near Lewiston, New York. Work to recondition contaminated facilities will continue at the Mound Laboratory in Miamisburg, Ohio. This 10-year project, which is equally funded by this program and by the Assistant Secretary for Defense Programs, began in 1978 and will be 61 percent completed by the end of FY 1984. Responsibility for the Shippingport plant will be taken over from Naval Reactors after all of the fuel has been shipped to the Idaho National Engineering Laboratory. Project offices will be established on the site by DOE and by the General Electric Company, which was selected in 1983 as the decommissioning operations contractor. Other activities in FY 1984 will include completion of an action plan for work to be done at Monticello, Utah. A geohydrologic study and an engineering analysis of alternatives for long-term management of the Weldon Spring site in Missouri will be completed and a draft environmental impact statement (EIS) will be initiated. Decommissioning of several contaminated buildings at Argonne National Laboratory also will be completed.

In FY 1985, the decontamination and dismantling of plant systems at the Shippingport Atomic Power Station will be initiated. The United States has proposed to the International Energy Agency that this be conducted as a limited cooperative project; details of the cooperation are under discussion. DOE will assure transfer of this technology to U.S. industry by providing opportunities for participation and by making the experience from the project widely available.

At the Niagara Falls Storage Site, the capping of the stored residues will be completed, the final EIS will be completed, and a DOE decision on the long-term management of these contaminated materials will be made. The decontamination and renovation of facilities will be continued at the Mound Laboratory and the project will reach 72 percent completion. Other activities in FY 1985 will include: removal of contaminated material and systems at Santa Susana, California; completion of the environmental review process for the uranium mill tailings site at Monticello, Utah; issuance of a draft EIS for long-term management of the uranium and thorium wastes stored at Weldon Spring, Missouri; removal of the TRIGA reactor vessel at the Center for Energy and Environmental Research, in Mayaguez, Puerto Rico; and the decommissioning of building 38 at Argonne National Laboratory.

WEST VALLEY DEMONSTRATION PROJECT

The objective of the West Valley Demonstration Project is to demonstrate the solidification process for disposal of high-level nuclear wastes under the provisions of Public Law 96-368, the West Valley Demonstration Project Act of 1980. An integrated production-scale development and demonstration project for treating the high-level liquid nuclear wastes at the Western New York Nuclear Service Center, near West Valley, will be carried out.

Major activities to be performed as part of the project include: (1) decontamination required to prepare existing facilities and equipment to accommodate the solidification project; (2) removal of the wastes from the underground storage tanks; (3) development, design, construction, and operation of systems and necessary supporting facilities for the solidification of the wastes; (4) acquisition of containers for the permanent disposal of the solidified waste; (5) temporary storage and transportation of the solidified waste to an appropriate Federal repository for permanent disposal; (6) decontamination and decommissioning of the waste tanks, facilities, hardware, and material used in carrying out the project; and (7) disposal of low-level and transuranic wastes produced from project activities.

The total Project cost is now estimated to be $381.5 million (unescalated) through waste solidification (exclusive of final decontamination and decommissioning of the facility).

In FY 1984 the major emphasis is on construction and decontamination. We plan to complete 60 percent of the construction of the vitrification Component Test Stand; procure the test stand melter, canister turntable, and other key components; complete construction and begin testing of waste mobilization and removal equipment in a one-sixth scale waste tank model; and complete verification testing for supernate processing equipment; complete decontamination of four radioactive areas and develop procedures for several more hot areas.

The funds requested for FY 1985 will be used to test and adapt installed equipment to support the beginning of supernate processing in April 1987 and sludge processing in September 1988. In particular, the program will complete and operate the vitrification Component Test Stand; initiate design for conversion of the test stand to radioactive operation; complete decontamination of priority hot cells; and initiate procurement of supernate treatment, low-level waste treatment, and nuclear waste assay equipment.

NUCLEAR WASTE TECHNOLOGY

The FY 1985 budget request for the Nuclear Waste Technology program is $13.3 million, a decrease of $1.0 million from the FY 1984 appropriation. The funds are distributed among program elements as follows:

Program Element	FY 1984	FY 1985
	(in millions)	
Low-Level Waste	$ 8.2	$ 6.5
Program Direction	5.6	6.3
Waste Treatment	0.5	0.5
Total	$14.3	$13.3

The goal of the Nuclear Waste Technology program is to develop acceptable technologies for the treatment of civilian radioactive wastes. The major activities are: (1) the Low-Level Waste Program which provides technical assistance to States to develop regional capability for the disposal of low-level radioactive waste; and (2) the Waste Treatment Program which develops nuclear waste treatment processes and waste forms suitable for transportation, storage, and disposal in a geologic repository.

LOW-LEVEL WASTE

Public Law 96-573, the "Low-Level Radioactive Waste Policy Act," assigned States the responsibility for disposal of commercial low-level radioactive waste (LLW) generated within their borders. The formation of regional compacts to carry out this responsibility was encouraged by the law. The goal of the Department's LLW program is to assist states in the development of an effective national LLW management system by 1986 and to evaluate this system in terms of operational efficiency by 1988. DOE involvement in active LLW disposal sites will also be completed by 1988.

During FY 1984, the LLW program will complete the development of a regional LLW data base and continue its demonstration in compact regions; continue State/regional technical and financial assistance; and initiate disposal site stabilization and closure demonstrations at existing closed sites. The program is cooperating with the Office of Civilian Radioactive Waste Management to develop criteria and procedures for implementing the LLW site transfers to DOE as called for in the Nuclear Waste Policy Act of 1982.

In FY 1985 the Low-Level Waste program will provide technical and financial assistance to a limited number of regions to support selection and operation of a new LLW disposal facility; support the correction of problems and stabilization at an existing disposal site; and support the utilization of advanced or innovative methods for the treatment of LLW.

WASTE TREATMENT

The objective of the Waste Treatment program is to develop and demonstrate technologies for the treatment and immobilization of nuclear fuel cycle radioactive wastes in forms acceptable for transportation, storage and ultimate disposal in a licensed repository. Specifically, high-level, transuranic, and sodium contaminated wastes are addressed. Over the years, methods for treating high-level and transuranic wastes have been developed. This program is now focused on determining the long-term reliability and maintainability of improved prototypical waste treatment systems and on testing and selecting acceptable waste forms for storage or permanent disposal in licensed facilities. The adequacy of these technologies is being demonstrated through their application to specific Departmental waste treatment efforts such as those at West Valley and Three Mile Island (TMI). Activities in this program are coordinated with other Departmental efforts related to fuel reprocessing; generation of special wastes; transportation; and terminal isolation of Department and commercial wastes.

In FY 1984, waste solidification activities will focus on vitrification process controls and quality verification methods for demonstrating that the glass waste products meet required specifications. Specifications for transuranic wastes will be completed and transuranic waste treatment process development will continue. Criteria and guidance for shallow land burial of sodium contaminated wastes will be field tested and verified, with a final program report issued in 1985.

Activities in FY 1985 will determine the operational reliability, safety, and process control flexibility of the ceramic melter system for solidification of high-level radioactive wastes. A series of ceramic melter system design, testing, operation, and decommissioning handbooks will be developed to aid future waste treatment users. Transuranic (TRU) waste treatment technology will be evaluated and further developed. Planned activities include assessment of treatment options; evaluation of nonradioactive treatment techniques; and conduct of radioactive tests. In addition, several proposed TRU treatment

R&D programs which involve the actual treatment of existing TRU contaminated equipment in commercial plants will be evaluated. Evaluation of methods for treating spent nuclear fuel for interim storage and permanent disposal in a geologic repository will be initiated. Planning and evaluation of candidate materials and processes for a second generation, advanced waste form for high level wastes from less-aged nuclear wastes anticipated after the year 2000 will be conducted.

THREE MILE ISLAND PROGRAM

The Three Mile Island (TMI) program is budgeted under the Converter Reactor Systems Program but is managed under the Office of Terminal Waste Disposal and Remedial Action. The objectives of this program are to acquire information and conduct R&D that will substantially enhance nuclear powerplant safety, reliability, and operation; and to ensure the means for safe disposal of abnormal nuclear wastes resulting from an accident.

In consonance with the Administration's policy that responsibility for commercial nuclear power activities resides in the private sector, the Department's TMI program is limited to research and development that will be of generic value to the development and safety of nuclear power and waste management. Responsibility for the costs of TMI cleanup remain with General Public Utilities (GPU), the owner of the facility.

The TMI activities are being implemented in accordance with a Memorandum of Understanding among DOE, NRC, the Electric Power Research Institute (EPRI), and GPU. The efforts of GPU are aimed at plant cleanup and recovery. The Department has developed a program work scope that enables obtaining important R&D information that would not otherwise be available from the TMI-2 cleanup effort. The DOE program is being conducted in a manner that avoids delaying the GPU cleanup schedule.

In accordance with a Memoranum of Understanding between DOE and NRC, the Department will acquire unique radioactive waste, including the damaged core, from TMI for research and development and for disposal. The cost of disposal will be reimbursed by GPU.

Two subprograms comprise the TMI program: the TMI Waste Immobilization and Reactor Evaluation Program and the TMI Data Acquisition Program. The FY 1985 Budget Request for this program is $32.2 million as compared to $37.0 million in FY 1984.

TMI Waste Immobilization and Reactor Evaluation

The objectives of this subprogram are: (1) to conduct research and development on immobilization of abnormal reactor waste products, and (2) to examine the TMI-2 reactor and core components in-situ and to support development activities associated with the reactor defueling; the data and information acquired will provide an improved basis for evaluating licensing criteria and requirements, analyzing causes and consequences of accidents, and improving the reliability of the design and operation of light water reactors. This subprogram was initiated in FY 1982.

The Reactor Evaluation activities include development associated with the examination, removal, and disposition of the reactor core and internals. This element also covers development of the special systems, equipment, facilities, and processes needed to accomplish the defueling operation, as well as performance of onsite examinations, tests, and evaluations required to handle the fuel effectively and expeditiously.

The development and engineering of systems, equipment and procedures for reactor plenum removal and storage and for reactor defueling and fuel transfer will be continued in FY 1984. Reactor vessel head removal will be accomplished and core disassembly activities will be intensified with the goal of plenum removal in 1985 and the start of defueling in late 1986. The development work will be directed. toward a thorough examination of the reactor internals and core. Substantial beneficial information and data on the condition of the reactor core and other internal components will be obtained. In addition, preparations will be completed to perform examinations of the fuel and debris and other reactor internal components to characterize the accident effects. The knowledge gained from this program will provide data required for evaluating present licensing criteria and requirements; developing future licensing criteria; assessing and developing computer models used to analyze the course and consequences of severe accidents and means to mitigate the effects of such accidents; and evaluating improvements to reactor design, operation, and maintenance.

The Waste Immobilization activities were initially focused on an effort to demonstrate the feasibility of vitrifying zeolite ion exchange materials. This effort was completed in FY 1983. Activities are now focusing on other techniques for the treatment of abnormal wastes produced at TMI. Long term sample observation is being performed to provide a more extensive data base. The knowledge gained from this program will contribute substantially to the technology for processing and disposing of unique waste forms resulting from commercial nuclear powerplant abnormal operations and accidents.

TMI Data Acquisition Program

The objective of this subprogram is to obtain R&D data of generic value to the safety of light water reactors. DOE and EPRI are sharing responsibility and costs for portions of this R&D program. Specifically, the Department is funding data gathering, research and development, and information transfer in the following major areas: instrumentation and electrical equipment survivability; behavior of radioactive products; data system and specimen archiving; and offsite fuel debris examination. EPRI has responsibility for R&D on mechanical and structural component reliability, pressure boundary recharacterization, and decontamination and dose reduction associated with the primary coolant system.

In FY 1985, DOE plans to complete the in-situ and offsite examination of selected instrumentation and electrical components outside of the reactor vessel to ascertain their condition, cause of failure, and features which affect survivability. Data obtained will be used to upgrade qualification standards, regulatory guides, and operating and maintenance standards, in order to improve operation of nuclear plants and increase the likelihood of recovery from abnormal events. Efforts will continue on acquiring and analyzing solid, liquid and gaseous samples to identify how various radioactive isotopes, which were released within the containment building during the accident, were transported and deposited. These data will be valuable in assessing the existing models for fission product release which are used in nuclear powerplant licensing. Efforts to prepare for the offsite fuel debris examination will be completed. The Technical Integration Office will continue its program management activities at the TMI-2 site. The computer data bank system will continue to collect, store, and transfer the data and documentation generated by the DOE's program during the GPU cleanup effort.

Madam Chairman, this completes my formal statement. If there are any questions, I would be pleased to answer them at this time.

Mrs. LLOYD. Thank you very much, Shelby, for your presentation.

Although we are moving toward more innovative programs, I still want to know how we defend spending 85 percent of all funding for the advanced reactors on the breeder with so little effort on our space reactor program and, really, no measurable funding on advanced reactors other than the HTGR program.

And the following question I'd like to ask is, what is the utility's role in the breeder program since they're not going to be customers for decades?

Dr. BREWER. We certainly must listen very carefully to the input from the utility sector. They are the ultimate customer. I have consulted extensively with utility leaders on the breeder program; they are still, as we all are, recovering from the trauma of losing Clinch River. We intend to continue to gain their input and their support. We will leave the utilities steering committee in place; we also have a major technical integrator role for the Electric Power Research Institute.

Mrs. LLOYD. But don't you feel that this is 85 percent of the funding going in this direction when we're not actually going to be moving in the direction of the breeder in the next decade? I agree with your statement that we are moving ahead with innovative programs or giving money to HTGR, but my question is the priorities—85 percent of the budget going into advanced breeder reactor programs.

Dr. BREWER. We do have a very vigorous space reactor program which was initiated several years ago; the funding for that program is not terribly robust, it's about $4.5 million——

Mrs. LLOYD. It's $5 million.

Dr. BREWER [continuing]. About $5 million. It is a tri-agency program; that does not reflect the total funding. We also have funding from NASA and the Department of Defense.

Mrs. LLOYD. I think we are basically in agreement on the programs that we should be working on. I think our disagreement is over the level of funding, and——

Dr. BREWER. Let me respond to that, Madam Chairman. I am reluctant to initiate programs and incur large mortgages until we can determine the market for the ultimate products of these programs. In the case of small reactors, we're looking at several potential markets: those in the 50 megawatt to 100 megawatt range, and then those in a range above 100 megawatts to, say, 500 megawatts that would be applicable to a utility company. I think it's premature to get into a hardware stage for many of these programs until the mission is very carefully defined and until the market is carefully defined. For example, in the space program we have the—the Department of Defense has not yet defined a specific mission and schedule, and they probably will not until mid-1985.

Mrs. LLOYD. Well, back to the fact that since 85 percent of the proposed $358 million for the 1985 budget is allotted for the breeder-based technology program, and realizing also this program has accrued an enormous resource in scientific and engineering talent as well as very large facilities, don't you think it would be prudent if we use this wealth in support of a broader range of nuclear R&D activities? Since this is in place, we could put it to work on light water reactors or space power reactors or other concepts, such as the PIUS reactor.

Dr. **Brewer**. Madam Chairman, there still remains a national priority to develop an inexhaustible energy source. And the concept that is farthest along in this country is the breeder; and as a national insurance policy, we feel that we must maintain a breeder program at a vigorous level, that we should not fall back and become world losers in this technology. We are in the base program, at the forefront of technology. Our fuel work is superior to that of any other breeder-developing nation. Our understanding and knowledge of sodium systems is more broad than any other breeder-developing nation, and we simply must stay alert and at the leading edge despite the fact that we are not going forward with a Federal demonstration at the intermediate level.

Mrs. **Lloyd**. Well, Shelby, my credentials of supporting Clinch River and the breeder program are pretty good around here, I think, and I certainly share your enthusiasm; but the point that I was trying to make, since we aren't going to move forward in this decade, that we might be just a little bit pragmatic and use this broad range of technology that we have here to support such programs as the space reactor, power reactors, and our modular HTGR's, that we not confine it merely to the breeder.

Dr. **Brewer**. Well, I think I would concur in that; if you put it that way—the thing that I was stressing is that we must not lose sight of the need to develop an inexhaustible energy source for the next century, and that we not fall back and become a nuclear banana republic in the international scene, that we maintain focus and direction as best we can under the condition of having no specific schedule.

Mrs. **Lloyd**. Moving on to a little bit of another area, the nuclear utilities seem to be suggesting that there's little need for a Federal R&D program, that the Government can improve the regulatory and licensing situation. Do you agree with this?

Dr. **Brewer**. I do not agree with that, Madam Chairman. I believe that research and development is crucial to the advance of our nuclear option. I do believe, however, that the problems that we face, the crucial problems that we face in the near term—in the next 12 months, 18 months, and we have not yet seen the full extent of the red ink—are institutional, financial, and regulatory in character, and those are nonresearch, nontechnical problems. We must address those very vigorously but, at the same time, we must look ahead to where we go beyond the traditional light water reactor option.

Mrs. **Lloyd**. One of our problems is the public's perception of safety involved in this. Is this going to have to be addressed, as well?

Dr. **Brewer**. Yes, and our safety record is unparalleled——

Mrs. **Lloyd**. Well, we know that, but it's——

Dr. **Brewer** (continuing). But the public doesn't know it.

Mrs. **Lloyd**. The public doesn't know it, and we've got a story to tell.

You mentioned the licensing reform bill. What do you feel the chances are of getting a licensing reform bill this year?

Dr. **Brewer.** I think, with the attention diverted to a national election and the recess schedule that you folks will probably have this year, the chances are—not impossible, but——

Mrs. **Lloyd.** Not exactly probable, in the present climate?

Dr. **Brewer.** Not probable.

Mrs. **Lloyd.** This is certainly the feeling of this member, as well. I wanted to find out really why the administration is closing out BRET. Is the feeling that it's not necessary now to close the breeder fuel cycle, or is it felt that this is not a problem now?

Dr. **Brewer.** The fuel cycle, historically, has been neglected in this country, both in the light water reactor program and the breeder program. One of the problems, quite bluntly, in going forward with a line item for BRET, was the budget constraint problem and the worry about a down-year mortgage——

Mrs. **Lloyd.** Well, you have got $480 million invested in this and FMEF and would we be using them effectively if we close out this program at this point?

Dr. **Brewer.** Well, we will continue to complete our fiscal year 1984 activities in accordance with the report language last year. I believe that we could possibly structure BRET in the down years to minimize the U.S. taxpayers' burden, and by that I mean a major foreign investment in BRET. The problem I face in defending BRET within the executive branch was the down-year funding profile, and if I can work my way around that problem, I think I can secure the support.

Mrs. **Lloyd.** You do not feel that there's an overlap with the Defense program? That is not the reason?

Dr. **Brewer.** No, the Defense project is a Defense project; it does not have the developmental components that the FMEF project has. The FMEF project was conceived as a demonstration, a pilot demonstration of breeder fuel reprocessing as well as a source for the civilian program to have its own plutonium for its developmental needs, and not continue to be a burden to the Defense community for plutonium.

Mrs. **Lloyd.** Well, one representative from HEDL expressed an interest in fuel testing for the HTGR program. Now, what is your opinion on the role that these breeder technology people would play in this program?

Dr. **Brewer.** I'm sorry——

Mrs. **Lloyd.** Do you want to wait until later on that one?

Dr. **Brewer.** I'll have to answer that one for the record.

[The information follows:]

HEDL has hundreds of man-years of experience in the design, development, testing, and evaluation of fuels and materials for both thermal and fast reactors. This wealth of knowledge and experience can be effectively mobilized on a breadth of fuel- or material-oriented technology tasks from concept development, through testing, to full-scale demonstration. It is in the national interest that this pool of knowledgeable talented personnel continue to be utilized effectively on carefully selected nuclear technology development programs.

Mr. **Chandler.** Will the gentlelady yield?

Mrs. **Lloyd.** I yield to the gentleman from Washington.

Mr. **Chandler.** If I could interject here at this point, while you're on the discussion of the BRET, I think it was—the point that was made very strongly in the testimony yesterday that I would appreciate your comment on, and that concerned the international cooperation and the assertion that if we drop the BRET program at this point, we really lose any opportunity for being a factor in that because we have nothing to trade, that we lose whatever momentum that we have gained. And I think that it would be interesting at this point, if you don't mind, Madam Chairman, if we ask for a comment on that.

Mrs. **Lloyd**. Well, I was getting ready to yield to you, Mr. Chandler, so I yield the time to you now.

Dr. **Brewer**. Mr. Chandler, I quite agree with the sense of your remark. The other breeder developing nations—France, Japan, United Kingdom—all have brought their breeder fuel cycle development along in a synchronous manner with their plant development line. France is building a breeder reprocessing line called Thor; the Japanese plan to build a breeder reprocessing line at Tokai Mura; the United Kingdom has built a breeder reprocessing line.

The problem that we faced in BRET was not one of policy or intent or merit. It was a concern about the down-year budget mortgage; and, as I suggested to Chairman Lloyd, I will be trying very hard in the coming year to seek other sources of investment other than the taxpayer, such as an international investment in BRET, to unburden to some extent the budget's down-years mortgage.

Mr. **Chandler**. As I heard your questions, I think you have pretty well covered those that I had in mind. If in examination of the record we find something else, I'll submit it to Dr. Brewer in writing and ask that he respond that way.

Thank you, Madam Chairman.

Mrs. **Lloyd**. Thank you very much, Mr. Chandler. Without objection—since so many of the members of this committee and all committees are having to do double duty, we can't appear at all of our subcommittee meetings as much as we would like to, so I hope you will agree to answer any questions in writing for the record.

I think that we must recognize that the BRET program was an initiative of this committee and we are very interested in the BRET program.

Let's turn now to the space reactor program, and I think we must move with a little more enhancement on the advanced reactor systems line and the space reactor program. I think there's a need to support more of an orderly and an efficient transition into engineering development, and I hope that funds could be provided to insure more thorough evaluation in 1985 of the technology and safety issues, as well. In light of this, why does the administration's budget show a decrease rather than an increase——

Dr. **Brewer**. Madam Chairman, as I said, the space reactor program SP–100 has not yet gotten to the point of hardware development and testing; that is phase II which will commence in the summer of 1985. And depending on the mission for the space reactor program, the Department will be designing, fabricating, and testing a prototype in the out years from 1986 forward to, say, 1990 or 1991. It's in those years that we will see a major upsweep in funding requirements; but at the current stage, the triagency program is trying to define a specific mission in some detail, and that is to say the power rating, its reliability attributes, the duration of performance, and so forth. At the present stage, it's a paper program.

Mrs. LLOYD. Well, I realize that; but is enough money involved in the program so that we can make the proper judgments to devise in future years?

Dr. BREWER. Could I ask Mr. Chipman to step to the table and——

Mrs. LLOYD. We'd look forward to hearing from Mr. Chipman.

Mr. CHIPMAN. In the space nuclear power program in general, as you correctly noted, Madam Chairman, the budget has gone down. I think that's clearly explained by a number of factors. The reactor area, in particular—you made note that in 1983 the spending was quite high, about $6.5 million. That was for a couple of reasons; it was significantly in excess of the MOU that we had signed with DARPA and NASA, significantly in excess of the requirements identified in that MOU. And that came about as a result of the continuing resolution that led to the 1983 budget in which we were able to identify some additional funds we could put into that program. The funding identified for the reactor in 1985 is $4.5 million, which is in excess of that required by the agreement of $4.1 million. So we believe that we are maintaining our support at adequate levels for the joint program as it is proceeding. And as Dr. Brewer correctly noted, we have not yet reached the stage of deciding to proceed agressively with a project, although I believe you will be hearing from Dr. Wright, who is the program manager for this joint effort, that he has some concepts about how we might move ahead for a several hundred million dollar program in the not-too-distant future.

Mrs. LLOYD. It's been called to my attention that I'm going to have to move into another direction, and I apologize for this, but we will have to stand in recess for about 5 minutes. Please excuse us.

[Short recess taken.]

Mrs. LLOYD. The subcommittee will come to order.

I apologize for the brief recess, but we are, as I stated earlier—all Members are wearing two or three hats in these days of budgetary decisions.

The recent OTA nuclear power study points to many difficulties with the nuclear power industry that you're well aware of, and they feel that they must be resolved in order for us to preserve the nuclear option. What is your involvement in compact reactor designs for remote siting applications, such as for our DOD bases?

Mr. CHIPMAN. Madam Chairman, there are really a couple of areas in which we've gotten involved. The military is very active in this area, as you know; but for the Department's purpose, we've been helping to support some survey report, primarily out of LANL, that looks both at civilian and other uses for small- or intermediate-sized reactors. And it also is taking a look at the historical performance in this area, the lessons that might be learned from those small and intermediate reactors that were built in the past and what the technology holds for the future; so we're actively involved in that area as sort of a subfunction of the breeder program.

We're also supporting—not on a government initiative basis, but rather as a support function—those private sector initiatives that are interested in pursuing the advanced technology, and particularly the liquid metal technology, for some of these military applications. We're aware, for example, that some of the contractors are interested in the liquid metal technologies for the near term; others are thinking in terms of light water technology near term, and the advanced concepts for more in the future for these small, military uses.

Mrs. LLOYD. Well, who has the basic responsibility for this program, Gordon?

Mr. CHIPMAN. Today, the responsibility primarily rests with the military, but the Department is involved with them.

Mrs. LLOYD. So these are Defense programs at DOE?

Mr. CHIPMAN. Yes, ma'am. What we have is a growing interest in the use of nuclear power for special power needs in the military being identified by some of the Services; and this is also being looked at with interest by the Department through Defense programs. And the nuclear energy portion of the Department is supporting this effort where our support has been asked for so far from a technology point of view. But we do not have what I would call a departmental reactor program underway at this time.

Mrs. LLOYD. But the overall responsibility is in with DOE?

Mr. CHIPMAN. Well, it's a broad program. Let me just check on something.

The primary responsibility for the overall effort is still with DOD, and they have been working in direct contact with DP, Defense programs, in the Department, and we have been working with Defense programs.

Mrs. LLOYD. But it actually has nothing to do with the weapons programs as such?

Mr. CHIPMAN. That's correct.

Mrs. LLOYD. But it's still under DOD because of the applications?

Mr. CHIPMAN. It's for their facilities; that's correct.

Mrs. LLOYD. But basically more of the applications would fall in the civilian—the technology would fall more in the civilian sector?

Mr. CHIPMAN. That is correct. They're looking very hard at the contractors that have produced the civilian powerplants and certainly, in the near term, they're not interested in exotic technologies; so it could almost be viewed as a technology that's off the shelf with minor design modifications. Keep in mind that they're looking at concepts that are generally smaller than we think are going to be readily of interest to the private sector.

Mrs. LLOYD. Thank you.

One final question. As we have stated many, many times, certainly the quality of our nuclear powerplants has not been perceived as being very high. This is a matter of perception; some instances are not perceived as being adequate, and the public is questioning the safety of 50 percent of the—50 percent of the public, excuse me, perceives that our safety is not adequate, in view of the fact that we have 100 percent safety record.

Shelby, in your 1985 budget under HTGR, high temperature gas reactors, you mention the following: "The technical approach is to utilize inherently low-power density of small HTGR's to minimize the need for engineered safety features." Would you please elaborate on what you mean by low-power density and describe how this provides for an inherently safe reactor?

Dr. BREWER. Madam Chairman, one of the attributes of the HTGR, one of its many fine attributes, is the lessening of need for engineered safety mechanisms. For one thing, if something unfortunate occurs you have a lot of time to correct it. There is a response time that is measured in days, not in hours or in minutes. Second, at low-power levels—that is to say, small high temperature gas reactors—it's possible to shut down the cooling system and, essentially, walk away from it. It's able to be cooled by natural processes; it does not require a forced, man-made cooling system. And for those reasons it has a great deal of attractiveness to systems or institutions which do not have the degree of technical maturity that our large U.S. utilities do.

Mrs. LLOYD. Several of our experts have testified, including yesterday's CRS, felt that smaller reactors also have an advantage in today's market and projected market over the larger, multimegawatt sized plants. What is your opinion on the advantages in cost or otherwise in fabricating and installing these small plants?

Dr. BREWER. The fundamental question, Madam Chairman, is whether the economies of scale—that is, the dollars per kilowatt of electricity when installed—can be overcome for a small machine by mass production and by standardization and by central shop fabrication. That is one question which we have not yet answered.

Another factor is the financial commitment that a utility would make with a small reactor—or ten small reactors versus one large reactor.

Mrs. LLOYD. Well, our witness from CRS said that they would be more attractive even if they should cost more because their bonds would stay healthy.

Dr. BREWER. Right. The coverage ratio is far superior because—well, the revenue per unit of equity investment or per unit of bond interest rate is better. And you don't have a large exposure to high levels of IDC—interest during construction—while the plant is under construction but not gaining revenue. You take smaller bites; you can follow the load better and avoid excessive financial exposure.

Mrs. LLOYD. Thank you very much.

Are there questions that any of the staff members would like to ask Dr. Brewer?

Yes?

Mr. CLEMENT. Dr. Brewer, let me ask you, do you see any technical impediment to designing a reactor, a control system, a heat exchange system—in fact, the entire plant in such a way that you could have a standard design that could be licensed in the same manner that the FAA now licenses airframes?

Dr. BREWER. I do not. The only impendiment, Mr. Clement, is the fact that historically we've been on an institutional path which has led to—well, I called it an ant farm a while ago, but it has led to just incredible diversity and complexity and custom-made products for each application, and that's just not the way to conduct a large national energy resource.

Mr. CLEMENT. But you see no impediment?

Dr. **Brewer**. I see no technical impediment.

Mr. **Clement**. Turning to another matter, let me ask—the administration has proposed to reprogram $2 million away from TMI cleanup in the present year. Can you explain why that reprograming is necessary?

Dr. **Brewer**. I will ask Dr. Coffman to answer in more detail, but let me describe the problem qualitatively.

We are working at TMI under a ceiling of $157 million for the total cost of the R&D program or project there; and as the GPU progress slows and their schedule revs down in the cleanup effort, it's prudent for us to pull back as well and preserve our fiscal resources because we've only got $159 million to work with, and we've already spent about $85 million or $90 million. Otherwise we would be marching in place and being eaten alive by a big fixed cost.

Mr. **Clement**. Can the committee then be assured that that $2 million will in fact be made available in later years?

Dr. **Brewer**. Yes. The $2 million—if that's the figure—look at it this way, we're preserving that $2 million for use on the project later in a more effective fashion. If we spent the $2 million now we would not have it later, and we cannot effectively use the $2 million now because we can't get to the core, we can't do this and we can't do that because the total GPU schedule has slowed down.

Mr. **Clement**. Have you been able to get that funding limit on the TMI R&D recomputed in constant dollars to adjust for inflation?

Dr. **Brewer**. Yes; the original Ed Meese letter, the figure was $123 million in 1982 dollars, I believe; the Office of Management and Budget has allowed that to be recomputed in then-year dollars, and the figure is now $159 million, in year-of-expenditure dollars.

Mr. **Clement**. All right. Can we expect that you will attempt to get that recomputed again for 1985 or 1986, before the program winds up?

Dr. **Brewer**. Yes; that's the usual OMB formulation; they apply an escalator to each year of an out-year budget.

Mr. **Clement**. Madam Chairman, with the Chair's permission, I have opening statements that were prepared for Mr. Walker, the ranking member of the subcommittee and for Mr. Winn, the ranking member of the full committee, who were both involved in other hearings this morning. Mr. Winn is involved in hearings concerning the situation in Beirut and the Marine withdrawal, and Mr. Walker is appearing before another committee at this time. Might I ask unanimous consent that they be inserted in the record after the Chair's opening statement?

Mrs. **Lloyd**. Without objection, they will be made a part of the record. And again, I would like to apologize to you, Dr. Brewer, for the lack of participation today; but it is one of those situations, as you know, that occurs every February.

Are there additional questions from the staff?

Yes?

Mr. **Milder**. Dr. Brewer, the report accompanying the 1984 energy authorization R&D bill had language calling for an intensive technology transfer effort for the water-cooled breeder. To date, the subcommittee has received no departmental response to this matter and I know that the language called for such a response. What is the Department's intention for responding to our committee's language last year requesting intensive technology transfer effort in the water-cooled breeder?

Dr. **Brewer**. I'll have to answer that for the record, Mr. Milder, but it is our intent to certainly obey the committee's instructions on all matters of this sort.

[The information follows:]

HOUSE SCIENCE AND TECHNOLOGY COMMITTEE QUESTION CONCERNING THE LIGHT WATER BREEDER PROGRAM

Question:

Report language accompanying the Committee's FY 84 authorization bill called for an intensive technology transfer effort for the Water Cooled Breeder. To date, the Subcommittee has not received a departmental response and I note the language calls for a response. What is DOE's intention for responding to the language of last year requesting an intensive technology transfer effort in the Water Cooled Breeder program?

Response:

The response to the language in the bill is that technology transfer is now and has been an important part of the Water Cooled Breeder program; accordingly it is not necessary to earmark a specific portion of the Water Cooled Breeder program funds for that purpose. The Department of Energy fully agrees with the Committee's desire to ensure industry's knowledge of the light water breeder technology. The Department believes actions being taken are accomplishing this goal.

Throughout the Light Water Breeder Reactor program extensive efforts have been made to disseminate the technology to the nuclear industry and to academia. This includes having:

a. entered into formal information exchange programs with the commercial reactor suppliers;

b. published over three hundred technical reports on the Light Water Breeder Reactor technology; and

c. presented or published in technical journals over 180 technical papers.

These reports and papers have been distributed to industry and universities, which have found various applications for the sophisticated computer codes and technology.

The General Accounting Office confirmed industry was knowledgeable about the Light Water Breeder Reactor program and wanted to know the results of the Department's core evaluation effort.

As part of its R&D effort to ensure a viable nuclear option for the future, the department will continue work applicable to the various reactor technologies - pressurized water, liquid metal, gas. Completing the core evaluation phase of the Light Water Breeder Reactor program is a vital part of this effort because it builds on the already substantial technology base established over more than a quarter century of operating numerous pressurized water reactor power generator plants.

A Light Water Breeder Reactor core successfully operated in the Shippingport Atomic Power Station generating electrical power for almost twice its original design life. The core evaluation work that remains to be done will:

a. provide important information that is equally of interest in non-breeding pressurized water reactor designs; specifically the performance of fuel, structural materials, and various engineered features in conditions of extended fuel burnup; and

b. determine the amount of breeding obtained - a fact of vital importance in being able to exploit the thorium/uranium-233 cycle which is an almost limitless resource.

In summary, advanced reactor technology, including Water Breeder Reactor technology, remains an important part of the Department's R&D effort. The General Accounting Office found that completing the Light Water Breeder Reactor core evaluation work as currently planned was worthwhile and the most cost effective way to complete the Light Water Breeder Reactor program.

Mrs. LLOYD. Dr. Dugan, do you have a question?

Dr. DUGAN. Yes. Shelby, we had two other questions here. One is, have you or your people been looking at how, particularly with the innovative concepts being explored, how the universities might become more involved? You know, we had the briefings at DOE and our impression was that, you know, it's really a noise level of involvement; and we understand it's a mature technology program, but with it being refocused on innovative designs, would there be more of an opportunity for universities?

Dr. BREWER. Yes; there will. There are several universities that we are interested in having participate for a number of reasons; a lot of good ideas get grown at universities. Second, the level of engineering, nuclear engineering training at our universities is in a sort of a depressed state, the same state that the nuclear industry is in, and we feel a responsibility in that regard, too.

Dr. DUGAN. The other question was—and maybe both you and Gordon could comment—is there some significant support from the breeder-based program people to the SP-100 program as regards variety of reactor concepts?

Dr. BREWER. Yes; the breeder program, as you know, is—there is spin-off in a lot of directions. Liquid metal is applicable to small package reactor types, remote applications, other exotic end uses. There's a good likelihood that the SP-100 will, in fact, be a liquid metal machine; I'm not willing to say that for sure until mid-1985, but we try to—Gordon tries to run the program to serve not only the main line effort, that is development of an inexhaustible energy resource, but also to find useful applications for the technology in a variety of other places.

Dr. DUGAN. It might be better to split that out, though, in future year budgets in a more definite fashion.

Dr. BREWER. Well, I think it's—the best way to put it is it's not really a budget issue or even a funding issue. It's more technology support. For example, we're providing irradiation services for the fuel concepts for the space reactor. We could get into the business of charging by amortizing our reactor facilities, but that's not the way we've proceeded so far.

Another major area is just in the general technology transfer. All the liquid metal technology that we have is available on an advise and consent basis with the people who are interested in working on the space technology. Materials is another area. We have irradiation capabilities to study materials; we have a great deal of material information. This whole support for advanced technologies that is coming out of the liquid metal technology program even spills over into the light water area. For example, we are this year going to be conducting some power ramp tests in the treat reactor for EPRI to look at the source term issues for light water reactors in one of our special loops. This is the kind of a thing that's available; it's not really a budget item because we're not spending departmental money directly on these activities.

Dr. DUGAN. As the Chairman indicated earlier, there's more than one subcommittee even on this committee that seems to be impatient about the level of funding in SP-100; they're very concerned that it's just not enough.

Mrs. LLOYD. Thank you very much, Dr. Dugan.

I would just like to close the hearing on one final note. I think you have expressed our concerns that we move ahead with the inherently-safe reactor concept. And I'm also concerned about another aspect involved with this concept. I think that we also have to sell this budget to the full House of Representatives, and I will be very frank about it, I'm very concerned about trying to sell a funding budget when 85 percent is going for this advanced breeder program. I think that we have to be very realistic about it, that the Congress is very concerned about spending this sort of money when the money is not so readily available. And I think if we would put more money toward the ISR concept, we'd have a much easier job of selling our budget this year.

Thank you very much for your participation and, if there are no further comments, the Committee stands adjourned.

[Whereupon, at 10:30 a.m., the committee recessed, to reconvene at the call of the Chair.]

AFTERNOON SESSION

The subcommittee reconvened, pursuant to notice, at 1:02 p.m., in room 2318, Rayburn House Office Building, Hon. Marilyn Lloyd (chairwoman of the subcommittee) presiding.

Mrs. LLOYD. The subcommittee on Energy Research and Production will come to order.

First of all, I ask unanimous consent that the subcommittee permit today's proceedings to be recorded and covered by the media and other persons. Without objection, so ordered.

Today we will hear from a very impressive array of outside witnesses on advanced reactor concepts with an emphasis on a suggested thrust of great interest to me and to Chairman Fuqua, that is, the inherently safe reactor initiative, (ISR).

I believe it would be useful to review a brief history of the manner in which this initiative originated and summarize the responses which we have received thus far.

Chairman Fuqua and I wrote Secretary of Energy Hodel last November 14 and pointed out the need for a new focus for a Federal R&D program which would assure the viability of the nuclear option in the United States' domestic energy production strategy. One initiative which would, in our opinion, improve prospects for the nuclear option enormously is a program to demonstrate a failsafe reactor concept.

On November 22, we wrote Dr. Gibbons of OTA a letter requesting a supplementary study to the OTA report entitled, "Nuclear Power in an Age of Uncertainty," which was also done at our request. We asked that the additional study concentrate on advanced reactor concepts including the modular HTGR, advanced LWR's, and breeder designs.

We believe that this budget cycle offers the Congress an opportunity to conduct a fundamental reexamination of reactor concepts and the associated regulations which might govern their commercial use. I also believe that a bold and innovative approach focused on the modular HTGR and other innovative concepts could dramatically improve the prospects for nuclear energy in this country. I would say to those who ask what is new about the HTGR, that in tomorrow's marketplace, reactor designs will have to not only protect public health but utility investments as well from the consequences of a catastrophic accident. We must improve the economics for the utility customer, and we must improve the safety characteristics in order to recover public acceptance of the nuclear option.

I have been delighted to hear of the new concepts emerging in the breeder program and we will be hearing about some of those innovative designs today. I am, however, displeased with the meager DOE request for the SP-100 program which is embarrassing in light of the President's commitment to a space station. I also have a considerable interest in advanced LWR's and, in particular, compact designs for remote siting.

As I have said before, the critical issue before us is the preservation of the nuclear power option in the country and I believe that, at a minimum, this will require the introduction of economically attractive, inherently safe, and certifiable reactor designs. If we are to realize our hopes and dreams for the "dawn of a second nuclear era," as Dr. Weinberg has called it, we must begin today to devise such a program which leads to the development of these desirable reactor concepts.

I want to hear everyone's view on this, and my only advice would be that this is no time for business as usual. We must be innovative. We must be creative and we must work together.

Our first panel consists of Dr. Bertram Wolfe, Dr. Harold Agnew—pardon me, Dr. Wolfe is not here—Dr. Agnew, Dr. Storrs, and Mr. Richard Walker. Would you gentlemen please proceed?

Dr. Agnew, would you please proceed? It is a pleasure to have you back with us.

Dr. AGNEW. Thank you very much. It is a pleasure to be here.

My name is Harold M. Agnew, and I am president of GA Technologies. With your consent, I would ask that my prepared testimony be made a part of the record along with a briefing document——

Mrs. LLOYD. Without objection, all of your prepared statements will be made a part of the record as well as your HTR program brochure.

Dr. AGNEW. Fine.

Mrs. LLOYD. And, you gentlemen may all proceed as you wish with the full knowledge that your complete statement is a part of the record.

Dr. AGNEW. Thank you very much, Madam Chairman.

STATEMENT OF DR. HAROLD M. AGNEW, PRESIDENT, GA TECHNOLOGIES

Dr. AGNEW. Listening to your opening remarks, I would almost like to ask that my presentation be yours and let it go at that. I think is was a superb summation of where we think we need to go in the future to bring about the second general of nuclear power.

The document which I referred to is a very fine document in that it shows where we have been, where we are now, and where we would like to go in the future. I hope that you and your staff do have time to look at it and analyze it.

We, of course, at GA, have been supporting the high temperature gas technology for a good many years and we would like to point out that the passive safety is common to both the modular and what has been called the integrated HTGR design. We have had a very good working relationship between Gas Cooled Reactor Associates, Combustion Engineering, General Electric, and all the other participants who have been advocating and working toward this particular technology.

I would like to have my brief remarks cover both the modular design and the integrated design. In modular design, it is very interesting that your committee suggested a power range which we had decided upon about 3 or 4 years as being the appropriate range to really have a passively safe system, essentially a walkaway system. About 5 years ago, we looked into seeing what we could do, what was the largest reactor we could build and have the features which you described. We came out somewhere between 250 and 350 megawatt thermal. So, your figure for where we should aim is right on the mark.

We believe that this can be done, achieve this essentially zero fission release under essentially all conceivable accident conditions simply by using passive means to remove the heat by conduction or radiation to external structures. We also believe that, contrary to past wisdom, the cost study indicates that individual modular units can have appreciably lower capital costs than one would have assumed in the past by scaling down the old technologies. I think, if we take into mind what we are trying to build, that overall the costs will be comparable on a kilowatt hour as one would have thought for very large plants but with these plants being designed specifically as small plants.

In addition to this, Bechtel has been doing some very interesting studies where they are pointing out that in an electrical generating plant, the balance of the plant is about 75 percent of the total installation cost. Now, if you can separate the balance of the plant from the unique safety requirements in the nuclear system, then you can effect tremendous savings. Of course, with modular design, we believe that one can indeed have those particular safety aspects which are connected with the nuclear system completely separate from those safety considerations with regard to the balance of the plant. This could effect tremendous savings in the total building of the plant.

So, we are looking at this and we would expect during the extent of the program to really nail down what the costs will be.

The reference design that we have looked at uses the pebble bed technology and I think you are aware that GA is very closely tied in with the German program which has opted for the pebble bed technology for the small reactors. We see some distinct advantages there. We would use the Fort St. Vrain type steam generators, and we are still assessing whether we should use the technology which is available from the liquid water reactors and the light water reactors or a steel pressure vessel or should we stay with the prestressed concrete vessel which has always been associated with the HTGR program.

We would estimate that the total cost for a 250 megawatt thermal reactor, to really do a prototype and test it, and this is what I think you were referring to to get the public confidence back, to test it in all these various modes, we believe the total program costs would be around $700 million, assuming we started with fiscal 1986 program authorization and we could achieve full power operation in fiscal year 1993. We think that is a objective, providing it was the dedicated program——

Mrs. LLOYD. When did you say full power operation in?

Dr. AGNEW. In 1993.

Mrs. LLOYD. Thank you.

Dr. AGNEW. However, we really believe that we have to get the Nuclear Regulatory Commission on board at the beginning so that they are hand in hand with us so that when we end up we will have a standardized license for this particular type of device. We have enjoyed this with our Triga reactors and research reactors. They are understood. They again are safe in this context, and if we have a standardized design, working with the NRC from the beginning of the program, we believe that a standard licensable design will have a very wide range of applications for incremental addition of electric generating capacity and for cogeneration of steam and electricity for process industries. Of course, the high temperature aspects of the particular reactor affords this which is something you cannot get from the light water reactors. You cannot get the high temperatures.

As we look down the road, the ability to use uranium, which represents about 90 percent of the total U.S. energy resources, to use that not only for generating electricity but for process heat for industry, I think, in the long run, will take care of the carbon dioxide problems and the so-called acid rain problems and other problems that are going to arise.

Of course, the committee is very well acquainted with the very low radiation exposure which is being experienced worldwide as far as the workers in the plants in gas cooled reactors. It ranges between—about a hundred times less than that experienced in water-plants.

On the integrated HTGR, which has been our mainline program, I think it is critical that we continue that program and complete the preliminary design which we believe we will have in hand in 2 more years. We collectively have been working toward that effort and I think that we just should get that complete design and have it on the shelf. Clearly, the design we have been working on lends itself to either a two loop system at about 1100 MWt, four loop system around 2,200 MWt, or even a six loop system if one needed to go that high.

There are complementary parts in the programs for the modular as well as for the integrated system, so what we would like to urge is that continued support, and I know your committee believes very strongly this way. We would like to recommend $52 million be appropriated. Of this, $2 for capital equipment—this is for fiscal year 1985—to cover both programs, the modular and the integrated design. In addition we think that the thorium recycle program, which has been supported at the Oak Ridge National Laboratory, should continue at a level of $4.5 million for fiscal 1985.

I should mention to you that the Federal Republic of Germany is going to spend an equal amount in the cooperative program, United States and German, on this recycle program.

Thank you, Madam Chairman, that completes my remarks.

[The prepared statement of Dr. Agnew follows:]

PREPARED STATEMENT OF DR. HAROLD M. AGNEW, PRESIDENT, GA TECHNOLOGIES, INC.

Madam Chairman:

I am Harold M. Agnew, President, GA Technologies Inc.

I appreciate your providing me this opportunity to testify before your Committee and to comment upon your initiative for an Inherently Safe Reactor (ISR) program based upon a "Modular" High Temperature Gas-Cooled Reactor (HTGR). Your Subcommittee specifically and the Congress at large has consistently supported continued research and development of the HTGR for many years and we believe that this has been a very prudent decision. We are especially gratified this year that the HTGR is an important part of the FY'85 Department of Energy Nuclear fission budget request recently submitted to the Congress by the President.

Before proceeding with my presentation of specific technical and program areas, I would like to acknowledge the contribution made to the HTGR program by the other participants, several of whom are represented on this Panel. Although GA is the principal contractor on the program, and has been the pioneer of HTGR technology in this country, the participation of these organizations has been vital to the continuing vitality of the program and to its prospects for success. First, Gas Cooled Reactor Associates (GCRA) the utility/user organization which provides to the program the current perspective and requirements of the ultimate user of HTGR systems and, in addition, performs for the Department of Energy the overall program coordination function. General Electric and Combustion Engineering bring into the program the experience and capability of their respective companies in the nuclear field. The Bechtel Group and United Engineers and Constructors are also major participants. Oak Ridge National Laboratory has been a key participant in the HTGR program since its inception and is responsible for a number of significant technical contributions to the system.

Although my testimony will deal principally with your proposed ISR - Modular HTGR Program, I will also address the Integrated HTGR Program (Loop design) and the Thorium Recycle program under the direction of the Oak Ridge National Laboratory.

In reviewing the nuclear industry in the U.S. today it is clear that there are a number of factors which contribute to its current depressed condition. Paramount among these are the lack of confidence in the safety of current nuclear systems by significant segments of the public, the regulatory agencies and other interested groups. If their confidence is not restored it will be difficult, if not impossible, for the full benefits of nuclear energy to be realized. It is for this reason that we at GA fully support your initiative for development and demonstration of an Inherently Safe Reactor System and we believe the objectives of your program can be met with the HTGR class of reactors. Through this initiative we can be instrumental in bringing into being a "second generation" nuclear power era. All HTGR's provide a high level of inherent safety from the use of inert helium as the coolant, a graphite reactor core and a ceramic fuel and fuel cladding which are stable to very high temperatures, and a very large thermal heat capacity which leads to slow thermal responses to postulated accidents.

The same features of the HTGR which contribute to nuclear safety also result in very low levels of radiation exposure to plant operating personnel. Although this has not been the focus of major attention to date, we believe that this is an area that will receive increasing attention in the future.

MODULAR HTGR PROGRAM

Studies of modular HTGRs have received increased emphasis over the past several years with support derived both from GA and from the ongoing DOE supported national program. This work has benefitted extensively from the experience derived from operating HTGRs in the U.S. and the Federal Republic of Germany. The majority of this activity has been devoted to optimizing the benefits to be derived from the inherent safety and simplicity of modular systems for use in the generation of electricity or the co-generation of electricity and high temperature steam for use by the process industries. During the past year significant efforts have also been initiated by Bechtel to reduce the overall plant costs by taking advantage of the simplicity and safety of the modular HTGR in the design and construction of the balance-of-plant. A part of the program activity has also been devoted to advanced higher temperature HTGR systems which may eventually be used for methane reforming, coal gasification, water splitting, etc.

The results of these studies to date have been very positive although they have not, in all instances, progressed to the stage where definitive judgments can be made. The following paragraphs summarize several conclusions that can be made from the completed studies.

Passive Safety

As indicated above, the HTGR class of reactors characteristically provides a high level of inherent safety which leads to essentially zero fission product release during normal operation or postulated accidents. For small modular HTGR's these features can be achieved with completely passive mechanisms.

The work done to date has shown that for modular plants in sizes of up to at least several hundred MW(t) there would be essentially zero release of fission products from the coated fuel particles in the core under normal or accident conditions. This can be accomplished by totally passive conduction and/or radiation of the heat away from the reactor core in an effective manner such that the HTGR TRISO-coated fuel particles will not reach temperatures which would cause significant fission product release from the coated fuel particles. This provides an unprecedented level of protection to the public and to the equity of the plant owner and operator. Further, assuming that the licensing authorities give full credit to this feature, this would allow simplification of the nuclear system, substantially reducing the requirements for nuclear grade equipment in the plant and allowing nuclear requirements to be localized - a key factor in reducing the balance-of-plant (and overall plant) costs.

Reduced Costs

Cost studies performed to date indicate that individual modular units can be expected to have substantially lower unit capital costs ($/kWe) than would be projected for "conventional" nuclear plants scaled down to the same size. This reduction results both from simplifications embodied in the design, the reduction in the number of safety related systems, localization of nuclear requirements, the saving inherent in an increased level of factory fabrication and from the shorter construction schedule. Additional reductions in unit cost would be expected to result from the deployment of multiple modules at a single site. Additional studies currently underway will provide a basis for assessing whether the reduced capital requirements and other benefits resulting from small HTGR systems are sufficient to result in the enthusiastic support of the utilities and the process industry.

Recommended Reference Small HTGR Concept

The major features of the reference concept are illustrated in Figure 1. The design is characterized by an integrated "in line" arrangement of all of the primary system components in a steel vessel. Key performance and design features are provided below:

Key Features of Reference Concept

Power level, MW(t)	250
Net power output, MW(e)	95
Power density, Watts/cc	4.1
Core type	Pebble Bed
System pressure, psia	1050
Core outlet temperature, F	1270
Core inlet temperature, F	688
Reactor vessel type	Steel
Steam generator type	4-helical bundle
Circulator type	4-horizontal mounted electric motor driven
Control type	Control and shut down rods in reflector
Refueling concept	Continuous, on line

Demonstrated features incorporated in the reference design include: Fort St. Vrain type steam generators; current pebble bed fuel technology; LWR presure vessel technology; and operating system and fuel temperatures and pressure below those demonstrated by operation of the Peach Bottom 1, AVR and Fort St. Vrain reactors. Additional evaluation of design alternatives would be required to optimize the reference concept.

The ongoing modular activities have indicated a number of promising design alternatives. Of particular interest is the substitution of a prestressed concrete reactor vessel (PCRV) for the steel vessel to take advantage of the special features of that system. These include the structural integrity provided by the redundant and inspectable prestressing system, the fact that the load bearing members are not subject to radiation embrittlement or thermal cycling, and also the resistance provided by the PCRV to damage of the reactor core and internals from external events.

Program Cost and Schedule

Based on the reference concept, GA has developed a first order cost estimate and schedule for a program leading to the operation of a prototype plant. Certain key assumptions are implicit in the information presented. First, the schedule for performance of the work would be adequately funded and the Nuclear Regulatory Commission would be in a position to evaluate the unique characteristics of the modular system and establish the licensing guidelines in a time frame consistent with the program goals. Second, the program would not be inhibited in the use of technologies developed outside of the U.S. Third, the program goals for the ISR prototype are well defined and stable and fourth, the program is organized to permit effective management.

The total cost for the design, development and construction of a 250 MW(t) prototype HTGR is estimated at $673 million (1983 dollars). The breakdown of costs is approximately $174 million for design, $132 million for development (and design verification) and $367 million for plant hardware and construction. In addition to the above, the cost of the initial core fabrication and uranium would be $20 million.

No estimate has been made as yet of the cost of operating the prototype plant during startup and test operations or during subsequent power operations. Similarly, no estimate has been made of offsetting revenues from the sale of steam or electricity or from revenues that might result from the sale of the plant by the government at its commercial value.

Assuming program authorization in FY 1986, it is estimated that this plant could achieve initial full power operation in FY 1993.

A key premise in achieving an early operational date and demonstrating the cost benefits associated with the modular system is the responsiveness from the Nuclear Regulatory Commission. This would require that the NRC be in a position to evaluate the unique characteristics of the modular system and establish the licensing guidelines in a time frame consistent with the program goals. Congressional guidance may be required to insure the level and timeliness of NRC participation. Further, to insure full benefit from the prototype project, the licensing approach should be structured to allow for NRC "type certification" of the modular design.

An important element of the recommended program is to subject the plant to a full series of tests to demonstrate its capability to remove the after-heat associated with accident conditions through passive mechanisms. Successful completion of these tests would provide a basis for NRC certification of the modular system. Certification testing would be undertaken following completion of normal startup and power operation testing.

Program Organization and Structure

GA recognizes that the ultimate organization and structure for carrying forth a prototype Modular HTGR project will be made by the Government. A key participant in any such project, however, would be a lead nuclear system designer/vendor - a role which GA is singularly qualified to assume. As indicated earlier, not only is GA the pioneer and only historic vendor of HTGRs in the U.S., it is also the prime repository of the technology. In addition, GA is the 45% owner in HRB (55% owned by Brown Boveri & Cie, Germany) the designer and builder of the two HTGRs in Germany. Through this association, GA would be able to bring to the project those technologies demonstrated in Germany which would be incorporated in an optimized modular plant design. If selected for this role, GA would plan to establish an integrated nuclear system project team including Combustion Engineering and other current participants in the HTGR national program.

Applications

The ultimate utilization and market for the modular HTGR will depend upon successfully demonstrating the technical features of the system and achieving an acceptable level of economics relative to alternative systems. A standardized, licensable (certified) design would have wide applicability for the incremental addition of electric generation capacity, and for the cogeneration of steam and electricity for the process industries. If the full economic promise is achieved, the system may also be deployed as multiple modules to provide a lower risk approach to addition of large blocks of generating capacity. If separation of the safety related functions is achieved, the modular system could also be considered as a retrofit heat source for existing fossil generating units which cannot conform to updated standards for emissions or for which the current fuel has become non-economic. The modular plant sizing and its level of safety also provides an opportunity to export nuclear power to countries previously excluded from the benefits of nuclear resources by lack of a small inherently safe reactor system.

In the future, the operating experience and technology base derived from the steam cycle plant will form a strong foundation for the deployment of higher temperature HTGRs adaptable to hydrocarbon reforming, coal gasification, and other advanced uses.

GA believes the Modular HTGR is a most promising concept and should receive increased emphasis in the FY'85 program with specific attention to refining the program requirements, economics and key areas of technology.

INTEGRATED HTGR

Our enthusiasm for the Committee's initiative for a small Modular HTGR does not lessen our support for the multi-hundred megawatt HTGR program. The emphasis of the current HTGR program supported by the Department of Energy is the 2240 MW(t) HTGR which is of the so-called "Integrated" design. The Integrated HTGR design is typified by a configuration in which the reactor core and primary loops are integrated within a single prestressed concrete reactor vessel (PCRV). This design provides a high degree of inherent safety. A two-loop Integrated HTGR which uses the same mechanical components and fuel as the 2240 MW(t) HTGR, would have a thermal rating of 1170 MW(t) with a net electrical output of 440 MW(e). The major difference between the two-loop and four-loop designs is in the sizing of the system integrating PCRV.

The two-loop HTGR appears to be in the size range of interest for concentrated industrial cogeneration applications while retaining flexibility through the addition of power loops to meet the future demand of the utilities for major additions of base load electric power production.

The assessments performed to date on the Integrated design HTGR indicate that the probability of a significant fission product release from the plant is well below that for other current reactor systems and many orders of magnitude below the interim NRC safety goals.

The major design changes incorporated in the Integrated HTGR from Fort St. Vrain have been made with the specific objectives of improving reliability and maintainability. These changes include the multi-cavity PCRV, a simplified motor driven helium circulator, the elimination of the reheat cycle, the lowering of the primary system operating temperatures and a reduction in power density. Also included in the design is the use of in-situ refueling which simplifies and speeds up the fuel replacement operations. Additional design improvements on the HTGR are anticipated from activities currently underway which will result in increased levels of inherent safety and reduced costs. These activities will include a review of the features of the 500 MW(e) plant (HTR-500) being designed in Germany by HRB, which has as its goal reaching competitive energy costs with 1300 MW(e) PWRs.

GA believes the Integrated HTGR should continue to receive support through the Department of Energy with the emphasis shifted to the two loop 1170 MW(t) version and modification to that design to accommodate higher levels of inherent safety and changing user requirements.

GA Technologies recommends that $52 million (including $2 million for capital equipment) be authorized in the FY'85 Department of Energy Authorization for the HTGR Program. This budget level would permit: continuation of the effort on the Integrated HTGR design; an increased effort on the Modular HTGR and substantial progress toward resolving the open questions of this concept; a continuation of a redirected technology program supportive of both the Integrated and Modular design efforts; and sustaining an effort on advanced, higher temperature versions of the HTGR systems.

Thorium Recycle

The Thorium Recycle Program, under the direction of the Oak Ridge National Laboratory, is a critical part of the National HTGR program which has been supported and funded by your Committee for many years. Unfortunately, there is no FY'85 funding for this program in the President's budget request. We would, therefore, recommend your Subcommittee authorize $4.5 million to continue work in the following HTGR fuel recycle areas: storage of HTGR spent fuel; development of designs and economics for rail and truck shipping of spent HTGR fuel; development and testing of volume reduction methods; and development of packaging and disposal forms. This work would cover both the prismatic and hexagonal fuel element configurations.

The U.S./Federal Republic of Germany cooperative spent fuel treatment program has provided an excellent example of a modestly funded program in both nations with major accomplishments. In FY'85, the FRG plans to spend roughly an equivalent amount to the $4.5M requested in our testimony.

In summary, Madam Chairman, GA Technologies recommends your Subcommittee authorize $52 million (including $2 million for capital equipment) for the HTGR Program and $4.5M for the Thorium Recycle Program.

I would request that the brochure entitled, "HTGR Program, February 1984" be made a part of the record of these proceedings.

Finally, thank you again for the opportunity to present GA's views before your Subcommittee.

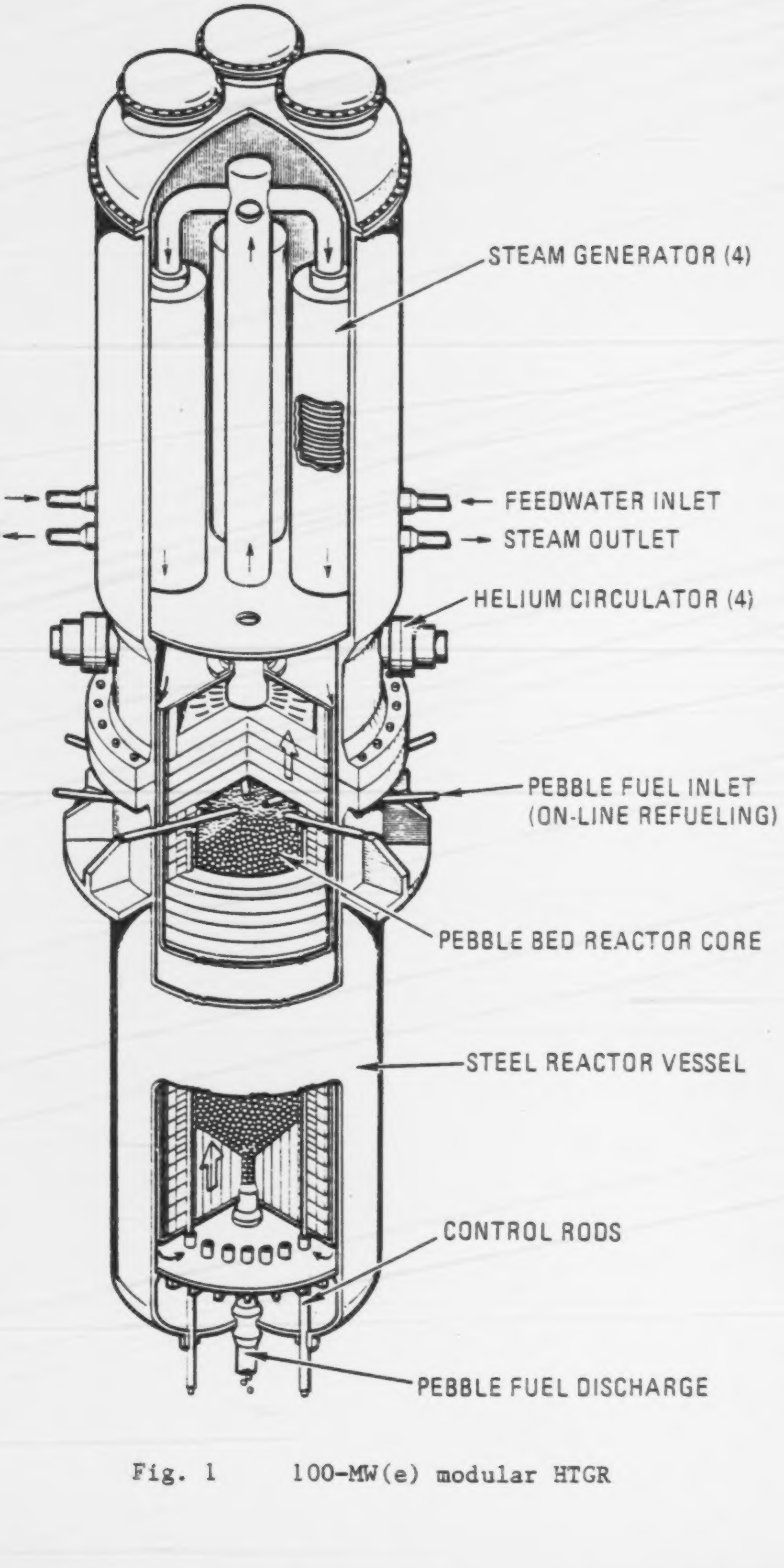

STEAM GENERATOR (4)
FEEDWATER INLET
STEAM OUTLET
HELIUM CIRCULATOR (4)
PEBBLE FUEL INLET
(ON-LINE REFUELING)
PEBBLE BED REACTOR CORE
STEEL REACTOR VESSEL
CONTROL RODS
PEBBLE FUEL DISCHARGE

Fig. 1 100-MW(e) modular HTGR

Mrs. LLOYD. Thank you very much, Dr. Agnew.

Dr. Storrs, would you proceed?

STATEMENT OF DR. CHARLES L. STORRS, DIRECTOR OF ADVANCED DEVELOPMENT, NUCLEAR POWER SYSTEMS, COMBUSTION ENGINEERING, INC.

Dr. STORRS. Madam Chairman, ladies and gentlemen, my name is Charles L. Storrs. I am director of advanced development, nuclear power systems, Combustion Engineering, Inc. I am please to have this opportunity to comment on the advanced reactor program for fiscal year 1985.

Conceptual design studies both in this country and in the Federal Republic of Germany have concluded that a sufficiently small HTGR can dissipate its decay heat to the environment during an accident situation for an indefinite period by radiation and conduction alone without exceeding the fuel temperature at which significant release of radioactivity would occur. No reliance need be placed on coolant circulation or pressure. Since the environment, in this case, includes a reactor vessel and concrete structures of considerable economic value, simple passive cooling systems will be desirable to protect the owner's investment, but these are not related to the health and safety of the public.

If these conclusions can be verified by a test program on a prototype reactor, including a test of loss of flow and pressure while operating at full power, no engineered add-on safety systems would be needed to assure public safety, and the balance of plant might be safely designed and built to commercial standards, as contrasted to nuclear safety standards with their heavy emphasis on quality assurance. The safety related requirements for the balance of plant would be minimal, permitting significant cost savings and reduced construction time. These features would go far toward eliminating the unacceptable uncertainty in costs and schedules for nuclear plants which, in our view, is the major obstacle to the use of nuclear power rather than safety per se.

Experience with the design and operation of HTGR's, specifically Peach Bottom No. 1, Fort St. Vrain, and the 15 MWe AVR at Julich in West Germany, shortly to be augmented by the 300 MWE THTR, supports the conclusion that HTGR's can be built, operated, and maintained in a practicable and straightforward manner with a minimum of additional R&D required.

The modular version of the HTGR thus represents the enticing vision of a reactor with passive and transparent safety, to use Dr. Weinberg's expression, that rests on a solid, demonstrated technological base. Furthermore, the HTGR has attracted continued, enthusiastic support from a large fraction of the U.S. utility industry, the eventual users of the development.

With respect to the public's perception of the safety of nuclear power, it is clear that few laymen are able to follow the technical details of safety assessments. The public is confused by different views expressed by experts about hazards to the public. On the one hand, the regulatory authorities require that each nuclear plant have elaborate plans, equipment, and practice drills for the evacuation of all residents for many miles around the plant. Noting this, the public is understandably reluctant to also accept the view that such serious accidents are impossible or so unlikely that they need not worry about them. Nuclear power is then not a good neighbor, and if nuclear plants are built at all, they should be somewhere else. To have an effect on public perception, an additional goal of an inherently safe reactor program should be to eliminate off-site evacuation requirements.

In closing these brief remarks which I have gone into in some greater depth in my testimony that I submitted, I would like to emphasize that we at Combustion Engineering do not regard increased safety as a panacea for the ailments of the nuclear industry. The present generation light water reactors have an excellent safety record. Economic and institutional problems seem to be of greater concern, in particular the perceived current excess generating capacity, the poor financial health of many utilities, that is to say, their difficulty in raising capital funds, and especially the great uncertainty in nuclear costs and schedules, some of which arise out of the licensing process.

Although we believe that the light water reactor has a promising long-term future, the attractive features of the HTGR, including its eventual applicaton to high temperature process heat, make it well worth continued development.

Thank you for the opportunity to testify.

[The prepared statement of Dr. Storrs follows:]

PREPARED STATEMENT OF DR. CHARLES L. STORRS, DIRECTOR OF ADVANCED DEVELOPMENT, NUCLEAR POWER SYSTEMS, COMBUSTION ENGINEERING, INC.

Madame Chairman, Ladies and Gentlemen. My name is Charles L. Storrs. I am Director of Advanced Development, Nuclear Power Systems, Combustion Engineering, Inc. I am pleased to have this opportunity to comment on the Advanced Reactor Development program for Fiscal Year 1985.

Combustion Engineering, Inc. is a supplier of fossil and nuclear powered steam supply systems to the utility industry. In addition, we supply fossil-fueled steam systems for industrial applications, and equipment and services for oil and gas exploration and production, among other things. Our interests therefore span a wide range of energy research and production, but I will largely confine my remarks this afternoon to the High Temperature Gas-Cooled Reactor.

The nuclear industry, as we are all painfully aware, is going through a severe depression in terms of new orders, and the cancellation of old orders, although the commissioning of new plants is at a peak rate. A large number of reasons can be cited for this hiatus, some of which may be amenable to resolution, or at least improvement, by means of the development of new designs or the incremental improvement of existing designs. A new design initiative should endeavor to address all or most of these topics. The list includes high capital cost, long construction time, uncertainties in licensing requirements, adequate quality assurance of safety-related equipment, owner's financial risk, simplicity and ease of operation, availability and maintainability, radiation exposure to plant workers, and last but not least public acceptance.

My purpose in reciting this list is to encourage a balanced perspective on the development of advanced reactor designs. There is no simple solution to the problems of the nuclear industry. Even public acceptance has several facets - proliferation and waste disposal come to mind - in addition to an improved perception of the safety of nuclear plants. Notwithstanding all this, an improvement in the perception of nuclear safety is an important objective. If this is accompanied by a reduction in onerous licensing requirements, many of the concerns listed above would also be alleviated.

ADVANTAGES OF MODULAR HTGR

Conceptual studies, both in this country and in the Federal Republic of Germany, have concluded that a sufficiently small HTGR (in the 200 MWt to 350 MWt range you have suggested) can dissipate its decay heat to the environment during an accident situation for an indefinite period by radiation and conduction alone without exceeding the fuel temperature at which significant release of radioactivity would occur. No reliance need be placed on coolant circulation or pressure. Since the "environment" includes a reactor vessel and concrete structures of considerable economic value, simple passive cooling systems will be desirable to protect the owner's investment, but these are not related to the health and safety of the public.

If these conclusions can be verified by a test program on a prototype reactor, including a test of loss of flow and pressure while operating at full power, no engineered add-on safety systems would be needed to assure public safety, and the balance-of-plant might be safely designed and built to commercial standards, as contrasted to nuclear safety standards with their heavy emphasis on quality assurance.

Experience with the design and operation of HTGR's, specifically Peach Bottom #1, Fort St. Vrain, and the 15 MWe AVR at Julich in West Germany (shortly to be augmented by the 300 MWe THTR), supports the conclusion that HTGR's can be built, operated, and maintained in a practicable and straight-forward manner, with a minimum of additional R&D required. The modular version of the HTGR thus presents the enticing vision of a reactor with inherent and "transparent" safety (to use Dr. Weinberg's expression) that rests on a solid, demonstrated technological base. Furthermore, the HTGR has attracted continued, enthusiastic support from a large fraction of the U.S. utility industry, the eventual users of the development.

ECONOMIC AND LICENSING CONSTRAINTS

Before letting our enthusiasm get out of hand, however, it is important to recognize that little reliable information is available as yet on the cost of a modular HTGR plant. In past experience, the economies of scale have inexorably driven the utility industry (and many others) in the direction of larger unit sizes. To offset these very real savings, it is essential to verify that, because of its inherent safety characteristics, a modular HTGR can be built and operated without the panoply of engineered safeguards and costly nuclear safety standards that are currently imposed on the balance-of-plant. The objective of the prototype test program must be to obtain from the NRC a "type certificate" (to use the aviation terminology) for the NSSS module. Furthermore, the operation of the reactor must be so docile that a single operating crew can operate multiple reactor modules in a generating plant.

If these objectives are met, we would then have a pre-licensed, standardized NSSS which could be supplied by qualified vendors. The safety-related requirements for the balance-of-plant would be minimal, permitting significant cost savings and reduced construction time. These features would go far toward eliminating the unacceptable uncertainty in costs and schedules for nuclear plants, which in our view is the major obstacle to the use of nuclear power, rather than safety per se.

It should be pointed out once again that achieving this goal is speculative at this time. It depends upon both the favorable outcome of engineering designs and cost estimates and upon eliminating most of the dependence upon the balance-of-plant for safety functions.

OTHER SAFETY CONSIDERATIONS

Nor should it be assumed that the HTGR has a unique advantage over all other modular reactor types in terms of passive decay heat removal. Heat rejection from the vessel to the reactor cavity is insensitive to the nature of the heat source. Heat must be transferred from the fuel to the vessel without exceeding fuel temperatures leading to the release of radioactivity. In a liquid-metal cooled reactor, for example, this can be done relatively easily by natural circulation of the coolant. What is unique about the modular HTGR is that in-vessel heat transfer for the accident situation can be done by radiation and conduction, and so does not depend upon the coolant. The safety significance of the integrity of the coolant boundary largely disappears.

[changed by E. [illegible]]

Passive decay heat removal is not the only consideration for inherent safety. Important contributions come from a large negative power coefficient, leading to inherently stable operation; long time constants; and a large margin to conditions leading to failure of fuel or equipment. These characteristics will greatly reduce (or in the ideal, eliminate) reliance upon extremely reliable and fast-responding control and protective sysems, and highly skilled operators.

With respect to the public's perception of the safety of nuclear power, it is clear that few laymen are able to follow the technical details of safety assessments. The public is confused by different views expressed by experts about hazards to the public. On the one hand the regulatory authorities require that each nuclear plant have elaborate plans, equipment and practice drills for the evacuation of all residents for many miles around the plant. Noting this, the public is understandably reluctant to also accept the view that such serious accidents are impossible or so unlikely that they need not worry about them. Nuclear power is then not a good neighbor, and if nuclear plants are built at all they should be somewhere else. To have an effect on public perception, an additional goal of an "inherently-safe reactor" program should be to eliminate off-site evacuation requirements.

PROGAMMATIC ASPECTS

From a programmatic standpoint, not enough conceptual design work has been done on the modular concept as yet to permit the effective application of a large-scale effort in FY 1985. Basic choices remain to be made, such as fuel configuration, type of pressure vessel, outlet temperature, configuration (in-line or side-by-side), and circulator location and temperature. It has not been established whether the technical and economic objectives portrayed above are feasible, in particular the very low release of radioactivity during unprotected accidents. If they are not, continued work on small modular reactors would have to be directed at other objectives, such as process heat. Some progress can be made in FY 1984, particularly if programmatic emphasis is changed, but still a modest and gradual buildup of effort in FY 1985 seems appropriate.

On the other hand, the 2240 MWt "Lead Project" on which several companies, including C-E, have been working for a number of years is an excellent design and has the consensus support of all program

participants, including the potential users. It should not be summarily cast aside, even though it is our view that the climate is not currently ripe for the utilities, suppliers, and Government to all make the necessary investments and to accept the risks needed for its construction. We recommend that work on the Lead Plant continue in an orderly manner, with a near-term transfer of additional effort to the modular program as the resources can be effectively applied, and contingent upon continued favorable technical and economic assessments from that program.

For the HTGR program to proceed effectively, strong leadership is needed, both programmatically and technically. Consideration should be given to the formation of a Program Office, staffed by full-time personnel seconded by the various program participants, which would provide the technical direction needed to coordinate the engineering and development activities. This Program Office would be the prime contractor to DOE, and all contributing organizations would work under subcontract to it. Such an arrangement has worked well in the past, and is in line with a substantial school of management theory.

Since the utilities are the ultimate users and owners of the HTGR, it is important that their views, requirements, and enthusiasm continue to provide guidance as the program proceeds. As a potential vendor of the standardized, pre-licensed modules discussed earlier, it is important to us that this product have ready customer acceptance. The Gas-Cooled Reactor Associates (GCRA) is doing an excellent job in this regard, and their role should be continued and formalized.

CONCLUSION

In closing, let me emphasize that we do not regard increased safety as a panacea for the ailments of the nuclear industry. The present generation LWR's have an excellent safety record. Economic and institutional problems seem to be of greater concern, in particular the perceived current excess generating capacity, the poor financial health of many utilities, and especially the great uncertainty in nuclear costs and schedules, some of which arise out of the licensing process. Even though we believe the LWR has a promising long-term future, the attractive features of the HTGR, including its eventual application to high temperature process heat, make it well worth continued development. It appears that Government support is an absolute necessity for development to proceed expeditiously.

I sincerely hope that aggressive investigation of new concepts such as the modular HTGR does not diminish efforts to improve the light water reactors on which we have accumulated so much experience. Many of the problems which will ultimately surface in connection with new concepts aren't even recognizable at the conceptual stage. A troublesome question facing all reactors is - How safe is safe enough? If a consensus answer can be developed for that question, standardized designs can be evolved which meet all of the safety requirements, and which are also simpler, more reliable, more constructible, more maintainable, more forgiving, and more economic.

Thank you for the opportunity to testify.

Ms. LLOYD. Thank you, Dr. Storrs.

Mr. Walker, you may proceed.

STATEMENT OF RICHARD F. WALKER, PRESIDENT AND CHIEF EXECUTIVE OFFICER, PUBLIC SERVICE CO. OF COLORADO

Mr. RICHARD F. WALKER. Thank you, Madam Chairman.

My name is Richard F. Walker. I am president and CEO of Public Service Co. of Colorado, and chairman of the Gas-Cooled Reactor Associates which is a utility organization representing about a third of the electric generating capacity in the United States. We were formed in 1978 and have our own staff funded solely by utility funds, and we have been about the business of keeping the HTGR our primary objective is to establish it as an attractive commercial alternative in a timely manner.

We gave a lot of thought to the size of the plant that we should be promoting and, in 1981, we picked a four loop, 855 MWe generating plant, HTGR, as our lead plant project. We would like to point out that this lead plant project, just like all the HTGR concepts regardless of size, do have characteristics of inherent safety, and less environmental impact, and less reliance on engineering safeguards, more flexibility and margin in criteria of licensing and investment, flexible siting, and, as Dr. Agnew so aptly pointed out, greatly reduced radiation exposure.

We have all recognized what has happened in the nuclear utility business both from a utility standpoint, which I am in, that we do have a case here where it is probably appropriate for all of us to look at where we are going to go in nuclear, not only in what type or whether we go nuclear or coal or whether we look over the size situation again. Our lead plant project, thanks to the funding of this committee, help of this committee, has progressed. In fiscal year 1984, our conceptual baseline design will be done on this plant which we think is a very good plant.

For fiscal year 1985, we would do cost updating and we do need to get involved with the NRC in licensing support in that area and continue that going and also to continue going to basic technology. We also feel it is appropriate with the increased interest, I might say, in many corners, on the size question to look maybe at smaller sizes.

We have done some survey of our own utility industry, and you do find some indication, probably more for financial and ability to license reasons than for economic or technical reasons, that maybe we should look at a smaller size. I would point out that not a lot of work has been done on the smaller sizes and we need to proceed carefully. There is an old adage, the less you know about something, the fewer the problems are, so we do need to keep that in mind.

Our program of work for the rest of this fiscal year and into 1985 would be, as I said before, to finish up the lead plant, the 855 MWe, to also look, as Dr. Agnew said, at say a two loop plant which would be around 400 MW. Your first impulse would be just to scale down the lead plant project and make it two loops instead of four, but we think it is worth more study than that to really look at that size from the 300 to 400 MW. You might do something different than in the lead plant project because of the size, and we think that needs to be looked at.

We also feel, and we have supported in the past, the modular plant design in the 100 MW, and we think it needs some work and some economic analysis to see whether it really fits in, because you are coming down a very long ways in the size. You will gain some in ability to operate in inherent safety, but these all have to be put together to be sure that we are going the right direction. I believe we do have time to take a careful look at all these three alternatives.

We would propose to do that, that we would make a comparison of the lead plant, ones about half that size, and the monster plant during this period of time. In fiscal year 1985 or maybe a little into 1986, we would come up with a final report on which our members then could decide exactly which way we ought to go.

We also support the $52 million figure that Dr. Agnew testified to and we think that is an appropriate level of funding to carry out all three of these objectives and would certainly support that.

I would like to thank the committee for the help you have given us in the past. You certainly have been a great part in keeping this technology going, and it hasn't been easy over the last 4 or 5 years. It is obvious why I am here. I have the only operating gas-cooled reactor in the United States. It is running well. We are down for the third refueling, and I hope there are many more and I hope I can be back in future years to testify, Madam Chairman.

Thank you very much.

[The prepared statement of Richard F. Walker follows:]

PREPARED STATEMENT OF RICHARD F. WALKER, PRESIDENT OF PUBLIC SERVICE COMPANY OF COLORADO AND CHAIRMAN OF GAS-COOLED REACTOR ASSOCIATES

Madam Chairman and Members of the Subcommittee, my name is Richard F. Walker, and I am President of Public Service Company of Colorado and Chairman of Gas-Cooled Reactor Associates (GCRA) which is a utility/user organization that supports the development of the High Temperature Gas-Cooled Reactor (HTGR). At present, the GCRA constituency represents approximately one-third of the installed generation capacity in the U.S. In addition, participating GCRA utilities have a substantial investment in and extensive experience with nuclear power. This background of nuclear experience provides GCRA with a sound base for evaluating the HTGR as a commercial alternative. GCRA's role is to apply this base of experience in guiding the development of the HTGR to be fully responsive to utility/user requirements. A GCRA staff, supported solely by utility funds, has been in place since 1978 conducting HTGR concept evaluations, Project planning and development activities, and Program integration support services to DOE, including the management of architect-engineer resources and other plant-level design development activities.

GCRA's objective is to establish the HTGR as an attractive commercial alternative in a timely manner. The approach to achieving this objective has been to establish a Lead Project from which commercial follow-on plants can be deployed. Despite the recent turmoil associated with nuclear energy, a systematic assessment of candidate HTGR systems, with the participation of potential vendors and owners, culminated in 1981 with the selection of a four-loop, 2240 MWt/855 MWe steam cycle plant as the reference Lead Project candidate. The market for this plant is the medium to large baseload capacity additions for electricity generation or cogeneration of steam and electricity, as well as the replacement market for retiring medium to large fossil and LWR plants. The Lead Project focus established to date has been responsive to the Congressional bases of support and has been instrumental in gaining Program stability.

The reference Lead Plant candidate, like all HTGR concepts, is characterized by unique features that distinguish it from the current generation of nuclear power systems. The most notable of these features is the inherent safety and low environmental impact characteristics that translate to less reliance on engineered safety systems, added margins for meeting certain licensing criteria, added margins for plant investment protection, greater siting flexibility and reduced radiation exposure of plant personnel. To date, the U.S. government and industry have invested approximately $1.5 billion in the HTGR, much of which is applicable to the Lead Plant. In particular, approximately $50 million has been invested in the conceptual design of the Lead Plant.

It is GCRA's position that the 2240 MWt HTGR is a viable candidate for a private sector Lead Project initiative. This position is supported by numerous independent assessments of the design and by operating experience with Fort St. Vrain and other gas-cooled reactors throughout the world. Confidence in the industry's ability to construct and operate plants of this size comes from recognition of the successes experienced by nuclear qualified utilities with large nuclear power facilities in the U.S. and abroad. Ongoing programmatic activities should emphasize the application of the conceptual baseline documentation, to be completed in FY 1984, for substantive pre-review interactions with the NRC on HTGR-specific licensing criteria.

During the past year, there have been a number of introspective studies and surveys, including a broad utility survey by GCRA, on the future of the nation's nuclear power industry. A recurrent message from these efforts is the need for the development of smaller, simpler nuclear power plants with minimal reliance on engineered safeguard systems. Within the HTGR Program, two smaller alternatives to the 2240 MWt system have been identified that offer added dimensions of simplicity that may translate to overall performance and economic advantages. In one approach, a 1170 MWt/425 MWe design has been configured that was originally conceived as a two loop version of the reference four loop Lead Plant. However, with an emerging market interest in plants of this size range, an optimized version of an HTGR in this size range should be evaluated. Some of the key areas that must be addressed are as follows:

1) The approach to decay heat removal, including the use of passive systems.

2) The number and size of primary system coolant loops, the configuration of the PCRV and the use of a confinement rather than the more expensive containment-type enclosure.

3) The optimum approach to multiple unit plants and the sharing of common systems and facilities, plus greater use of modularity and conventional fossil plant construction standards.

4) The closer evaluation of the features of the German HTR-500 (MWe) concept that is targeted for project commitment decisions by the end of 1985.

In the second alternative to the 2240 MWt system, an HTGR Modular Reactor System (MRS) has been conceived as independent reactor units of approximately 250 MWt/100 MWe that can be constructed as a cluster of modules or sequentially constructed to more closely match load growth requirements and reduce utility cash flow needs. Design work on the MRS is relatively recent, and less than $5M has been invested in defining and evaluating the concept. However, much of the technology investment for the Lead Plant is applicable for the MRS. Further, much of the HTGR technology investment in the Federal Republic of Germany, including the AVR developmental plant and the THTR demonstration plant, may be particularly applicable to the MRS concept.

The intent of the MRS concept is to extend the application of inherent safety such that decay heat removal is accomplished by the passive mechanisms of radiation, conduction, and natural convection without reliance on active engineered safeguard systems. The concept is based on limiting the core size and power density such that the fuel particle coatings retain the fission products to an acceptable degree (yet to be defined) under all circumstances, including the loss of all forced circulation or loss of primary coolant. The economic challenge of the MRS concept is for the design simplicity afforded by the passive safety attributes to offset the economy of scale advantages of larger, integrated nuclear plants. To do so, it is intended that the nuclear steam (or heat) supply system will be shop fabricated to nuclear standards and the balance of plant field erected to predominantly conventional fossil plant standards. This approach is expected to improve the low productivities, extended schedules and high field erection costs encountered on most of the recent nuclear projects.

The MRS concept is in the early stages of evaluation. Some of the key issues that must be addressed are as follows:

1) Sufficient design must be conducted to support economic analyses that will examine sensitivities in the costs and schedules for the modular HTGRs versus the integrated HTGRs and the other alternatives.

2) The safety goals of the MRS must be specifically defined and translated to licensing requirements and engineering terms. Key issues are the development and acceptance of design basis events, source terms and allowable fission product releases.

3) The design and development programs required to demonstrate the unique, inherent safety features of the MRS must be defined. Central to the MRS concept is the use of a fuel for which high integrity and low fission product release can be assured under all postulated reactor conditions. These design requirements place provisions on fuel manufacturing and performance that require extensive verification.

If commercial feasibility of the MRS is established, it is envisioned to serve the small to medium baseload generation and cogeneration markets as well as the replacement market for some of the retiring oil and gas-fired units that have been used for baseload applications. Further, the unit size of the MRS makes it particularly attractive as an export product to developing nations. It is GCRA's view that the MRS concept has significant technical and licensing potential. If economic incentives for the MRS are borne out in thorough technical studies, there will be justifiably strong utility/user support.

Common to any of the HTGR concepts and potential Lead Projects is the need to address the key institutional issues of licensing reform, vendor development, program management and Project development responsibilities, and long-term budget stability. With regard to the latter issue, we are most heartened that the DOE has included the HTGR Program within their FY 1985 budget proposals to Congress at a level of approximately $35 million.

In order to complete the concept evaluation of the mid-size integrated plant and the MRS by the end of FY 1985, we respectfully recommend that the HTGR Program at DOE be funded at an increased level of $52 million in FY 1985. In particular, GCRA estimates a $15 million effort will be required to complete the ongoing MRS concept evaluation. Pending a positive outcome from this effort, a MRS Lead Project conceptual design could start in 1986. For the ongoing integrated plant design effort, GCRA estimates a $12 million effort will be required in FY 1985 to evaluate a mid-size plant and to establish the overall optimum approach for an integrated HTGR design. During this period, the technology development programs should be maintained at a level of $25 million, including $2 million for R&D equipment. The emphasis of the technology development should be toward the resolution of the critical technical and licensing issues that affect any Lead Project commitment decision. In addition, the HTGR spent fuel treatment program at DOE should be maintained with continued emphasis on spent fuel volume reduction, storage and disposal. In parallel with the DOE-funded development activities for the integrated and modular HTGR designs, ongoing Lead Project site and institutional development activities will be continued by GCRA and other prospective Project participants with the goal of selecting the optimum Lead Plant system by the end of FY 1985. Utility resources through GCRA have continued to increase in this area with approximately $2.5 million contributed in 1983 and approximately $3 million budgeted for 1984.

On the local front, I am pleased to report that 1983 has been another year of improving performance for Fort St. Vrain. As you know, the the Fort St. Vrain power plant first went critical in January 1974, achieved a 70% power level in January 1978, and was limited to that level by the NRC. In November 1982, after an extensive corrective program was completed by GA Technologies to resolve core temperature fluctuations, the NRC granted authorization to routinely operate at 100% power. In addition, the Public Service Company of Colorado continues to make investments in the plant that support its continued invaluable demonstration role. In 1983, we spent approximately $10 million and $9.3 million has been budgeted for 1984.

Fort St. Vrain has provided critical confirmation and demonstration of many key HTGR concepts. In particular, fuel integrity and radiation exposure to plant personnel have had an exceptional operating record. Operating data indicate that the amount of radioactivity carried in the helium coolant has been less than two percent of the design limit, demonstrating the structural integrity of the coated fuel particles and the graphite core structure. A comparison of personnel exposure data for Fort St. Vrain and light water reactor plants in the U.S. indicates that Fort St. Vrain has had an average annual person-rem exposure rate per GW(e)-year of less than two percent of the average exposure rate in light water reactor plants. This low personnel exposure level is even more significant in view of the fact that Fort St. Vrain has virtually unlimited access into the reactor building for all operations and maintenance personnel. Other major contributions of Fort St. Vrain have been in the areas of core physics confirmation, plant control and response, and plant performance. Plant operating experience to date has demonstrated predictable performance even during extreme modes of operation, including temporary loss of forced cooling. The high core heat capacity has shown temperature transients to be slow, predictable, and easily controlled. Operation to date has achieved 1400°F primary loop helium temperatures, 1000°F steam temperatures, and a net efficiency of 38.5%--the highest of any nuclear plant in the U.S. As of year-end 1983, the Fort St. Vrain plant has delivered approximately 3.8 billion kilowatt-hours of net electrical energy, and in 1983, the plant exhibited its most satisfactory continuous run. We are confident that Fort St. Vrain will continue to provide valuable kilowatt-hours for our customers as well as critical information regarding the demonstration of many HTGR systems and components. My Company is proud of our role as owner/operator of Fort St. Vrain.

Madam Chairman, we appreciate the opportunity to present the utility/user support and perspective on the HTGR Program to your Subcommittee. With your continued support, we will bring to fruition an HTGR Program that is responsive to utility needs and the Nation as a whole.

Mrs. LLOYD. Thank you very much, Mr. Walker. I would like to say we thank you for keeping the program alive.

I would now like to recognize the ranking Republican on our committee, Mr. Walker, for his comments.

Congressman ROBERT WALKER. Thank you, Madam Chairman.

I will be brief, but it is obvious, as we listen to these witnesses and as we listened to witnesses yesterday, that we must move to channelize our research and development efforts toward development of a new generation of reactors which are engineered from the ground up to be safe, so safe that accidents such as Three Mile Island and some of the other things that have plagued the industry can never happen again.

I think that what we are hearing here are the kinds of ideas that will move an industry forward that some people are beginning to write off now. I think we in this committee know that that is the wrong kind of message to be sending, that we need to have a nuclear future in this country. The kinds of things that we do as a subcommittee and we do with the help of some of the people who have been before us testifying here over the last couple of days are going to help assure that future.

Therefore, I look forward to joining with you in that.

I do have some prepared remarks, Madam Chairman, which I would like to have made part of the record at the place appropriate for that, and I would simply submit them for inclusion.

Mrs. LLOYD. Without objection, they will be made a part of the record.

I told our participants this morning that we are all wearing two or three hats right now because we do have so many committee meetings going on, and it is not because there is any lack of interest in this committee for the great programs that we hope to fund this year.

[Prepared statement of Congressman Walker follows:]

PREPARED STATEMENT BY THE HONORABLE ROBERT S. WALKER

Yesterday we heard from a number of witnesses who represented a broad range of experience in the nuclear arena. The consensus of that group was that the future of nuclear energy in this country will be limited by the degree of public support which is currently very low due to public perception that there is a public health and safety issue, and secondly, and perhaps more importantly, that the costs of construction of nuclear plants have gotten so far out of control that utilities can no longer afford to opt for nuclear plants.

The causes of both problems are complex, and obviously go beyond the limited jurisdiction of this subcommittee. However, there are some things which we can do to improve the nuclear climate in America.

In a world in which we still are dependent on energy imports and in which so much of our dependence centers in the unstable Middle East, we cannot, and must not, allow ourselves to lose access to the nuclear alternative.

It was obvious to me as I listened to our witnesses yesterday that we must move to channalize our R&D efforts toward development of a new generation of reactors which are engineered from the ground up to be safe—so safe that accidents such as Three Mile Island can never again occur.

And we need a new concept in reactors. A common design, built, if necessary, in factories, so that we have the same people, building the same reactor today, that they built yesterday, and which they will also build tomorrow. We need a reactor, or a group of reactors, which can be licensed in the same way that the FAA certifies an air-frame.

If we can develop this inherently Safe Reactor concept, and if other committees of the Congress can move forward in the area of regulatory relief, we can once more see nuclear power becoming a viable part of our energy future. If we cannot, I see no reasonable expectation that we will have any nuclear future whatsoever.

Moving to another area which is of considerable interest to me in particular, and to the Committee as well, we are deeply concerned that the clean-up effort at Three Mile Island is falling further behind schedule. It appears that there have been numerous internal problems which are adversely affecting the research which this Committee has authorized on the island, and we are also concerned that the integrity issues involving the management of the company must be resolved before we can move forward. I have asked Chairman Lloyd for a hearing on this matter in the near future and I expect that we will go into it in considerable depth at that time.

Finally, I am concerned about the progress of the space nuclear reactor program. In the past this effort has had a fairly low priority, but with the announcement of the space station program the space reactor obviously takes on far greater urgency. It appears to me that there may not be sufficient attention being paid to this program in the current budget proposal.

Mrs. LLOYD. My question, what I really question, is the industry ready to utilize the advantages, such as more effective quality control and simplification of licensing as well as factory assembly and shorter schedule and lower financial costs that will be associated with factory manufacturing?

When the OTA studied standardization of plant design, they found that institutional barriers impaired this approach to standardization, so I would like you distinguished gentlemen to elaborate and perhaps alleviate these concerns.

Mr. Walker, do you think that the Gas-Cooled Reactor Associates would be interested in being a team member to furnish the design criteria for the modular HTGR so that utility customer requirements can be included in the design?

Mr. RICHARD WALKER. Yes. As I indicated in my remarks, we think this is something that ought to be looked at. When you get down to what our customers want, there are several things they want, of course. One is relief from rising electrical costs, and all of us face that all over. So we have to be careful which way we go so that we make a correct balance between technical, economic, and safety considerations. Certainly, the modular or smaller one has some real advantages from maybe simplicity of operation and from safety, but the laws of economics or scale still apply, and we have to be very careful that we don't get down too small that we get too many pieces to operate and it is an uneconomic operation.

As I indicated before, we are just getting into the modular design. We have been into the other a long time. I don't know of any real fundamental problems that might come up by bringing size down. Generally, the problems occur when you go up, but the fact remains that it has not been done, and we would be going to some new systems, some new configurations. The attractiveness of being able to go to a factory and buy the thing all assembled, all tested, all the things we have to do in the field, certainly has some appeal to us, but except for Dr. Agnew's TRIGA reactor, the small ones, which they do manufacture, you can test it, there has been no reactor of this size ever factory fabricated, tested, made critical, and that you have that you could walk out the door with. That is a heck of a good objective, but my only warning is let's step back a little bit and look and be sure that we aren't overlooking something so that the economics are really there along with the inherent safety that would obviously go with the kind of design that we are talking about.

Mrs. LLOYD. Dr. Storrs, since you represent Combustion Engineering, in terms of weight and physical dimensions, what is the largest size reactor that could be manufactured in a shop and be shipped to a field?

Dr. STORRS. That is a little tough to answer categorically. I had hoped you would ask—I will answer the question I had hoped you would ask. [Laughter.]

Mrs. LLOYD. Why don't you just answer the question you had hoped I would ask and then we will get back to it.

Dr. STORRS. The size we are talking about, the 100 MWe or 250 to 350 MWt could indeed be manufactured in the shop completely and tested—I would conceive of its being tested without loading the fuel, but short of that—and would be transportable to the site, perhaps in two pieces. However, that would depend upon exactly how you built it. In terms of the weight and diameter, I don't think there is a problem, but in terms of the total length, it might be difficult to transport it.

However, the concept is indeed one of having all the safety features in that large vessel or two large vessels that are connected together so that they can be tested. All the QA and the control and the NRC inspection would be done in the factory.

Mrs. LLOYD. Would a river port enhance the shipping, say, the shipping potential?

Dr. STORRS. We are probably talking water shipment, barge shipment, at this point, but that depends on where you are going, of course.

Mrs. LLOYD. Or where you are coming from.

Dr. STORRS. And where you are coming from.

Mrs. LLOYD. In addition to the reactor itself, what other major systems could be assembled in a shop, and would shop assembly really enhance the quality assurance situation? Are there some things we shouldn't do in a shop?

Dr. STORRS. No, I would say the reactor vessel and the steam generator and the circulator all put together in the shop and shipped as a unit or, perhaps, disassembled into two pieces and then shipped. Those would then encompass all the—most, not all of the safety related parts. Meanwhile, the balance of plant which is the civil works, the concrete, steel, and excavation and so forth, can be done at the site, and since it would not be safety related, it would be done essentially to commercial standards which would be much quicker, much cheaper. That is about 80 percent of the cost.

Therefore, the reason that we have hoped that this will turn out all right is that although we make 20 percent of the cost, that piece goes up, the 80 percent of the cost comes down, and that has a big influence on the total. However, as is clear from what Mr. Walker said and in my testimony I pointed out that we really don't know how those figures—we aren't really that confident in those figures at this point until we have done some design work and studied this problem a little more. We can't be very dogmatic and say this is what the plant will cost.

Mrs. LLOYD. Thank you.

I think we all know that the quality of our nuclear plants have really not been perceived to be too high in the safety of plants. They are certainly highly questioned by the public at this time. Dr.

Agnew, would you explain how the lessons that you have learned from Fort St. Vrain can benefit the work on the modular HTGR to remove some of the questionability?

Dr. AGNEW. I think one of the main lessons we have learned is don't start to build something until you have the design. With all respect to all the participants, we really started off without having design in hand, without having a program to test the various components together in whatever systems they were to be later operated in. I think that has been one major lesson that we have learned.

Another lesson I would say is that somebody has to be in charge from the beginning, and the funding has to be adequate so that we don't skimp, so that you can build in redundancy where redundancy should be built in.

I think another lesson we learned is that you must have the NRC on board at the beginning so that if you are half-way done, somebody doesn't come in with a new or change order which could—this particular type of device really caused tremendous slippage of schedule or very awkward operating conditions because the requirement which had been known about originally could have been taken care of, could have been an integral part of the plant, and we would have no problems.

So, I think those were the main lessons. We have continuously with the cooperation of the Public Service of Colorado, gone step-by-step, whenever these has been a slight glitch in the plant for whatever, we have analyzed what was the cost of that, was it something that in the future we could design so that would not happen, and we have prepared quite a bible of lessons learned. We have done this because, as you are aware, we are very much interested in using this technology in the years ahead when production reactor replacements will be coming out.

Mr. LLOYD. It is my understanding that several events occurred last year at Fort St. Vrain where operator error resulted in the plant's shutdown. Could you tell us how the gas reactor provided a safety margin during these events?

Dr. AGNEW. Let me start out with my perception because I read his reports, I think, sometimes before he has a chance to read them.

Mrs. LLOYD. All three of you may wish to comment on this.

Dr. AGNEW. There have been some instances where items or equipments not related to the reactor—reactor in the nuclear sense—have tripped for various reasons. In all cases, the plant has been able to restart in a very short time with absolutely no damage or problems to the plant whatsoever. There have been instances where I have learned of a mechanic doing something, had dropped a wrench or something, and the plant just, with its very large heat capacity, very forgiving nature, has caused no problems as far as I know toward—rather, essentially immediately start up in 10 or 15 minutes, within a half an hour, but I think Mr. Walker can best answer that. From the context of your question, I think the plant has behaved as designed.

Mrs. LLOYD. Thank you.

Mr. Walker?

Mr. RICHARD WALKER. May I comment, Madam Chairman?

Mrs. LLOYD. You certainly may.

Mr. **Richard Walker**. Through the course of the plant, or course, being the first of a kind, and as Harold said, some of the lessons learned, we didn't have enough redundant systems, we didn't leave enough space for some of the things, and we made the plant too complicated, frankly. So, there are certain interactions in systems and when an operator would do one thing, this would trip one loop which would trip the other, and we have had some of this over the years.

The frequency of trips have gotten less, and we have had our longest, almost continuous run since July of last year into January when we shutdown for the third refueling. However, I think the point that Harold is talking about and you possibly have reference to is the ability of the plant to withstand these things with no safety problems. It is a nuisance to have a plant shutdown, and we have had some problems in the past about water ingress into the helium under certain situations through the helium circulator auxilliary systems. That has caused us some real problems, and some of our longer down times have been due to the moisture problem that developed in getting moisture out of the helium. We think we have a good handle on these, thanks to working with Harold's people and the special task force and some system modifications at some great expense to us, but we have that pretty well under control. In the last 6 or 7 months we haven't experienced this water ingress problem to any major extent, so we are learning and it is getting better and it does verify many of the things that we have talked about today.

Mrs. **Lloyd**. All right.

Dr. **Agnew**. If I might add on the circulator, the water ingress, we have now, as part of the program which you have been supporting, starting up that GA circulator design and bearing and the system patroling. That will be extensively tested, whereas in the Fort St. Vrain design, the system was put together and it has not been previously tested, the total system.

Mrs. Lloyed. Thank you very much.

Do you gentlemen agree that your recommendation to this committee for the HTGR program funding at $52 million?

[Witnesses responded yes.]

Mrs. Lloyed. You agree.

I want to pick up on something you said, Dr. Storrs. I think that we have talked in the hearing yesterday and today also that even with our new concept of reactor that we are still going to have to tell the public this is a safe reactor, it is inherently a safe reactor. I think there are some Lessions that I hope that we can learn from our LWR program, that if we mean something that we should say it.

Now, if we have a 100 percent safety record, which we do, why in heaven's name do we have to have evacuation route sign? I Live near the Sequoia plant in Chattanooga, and it distresses me to go home and talk about the proven safety record of our nuclear plants at the same time have more and more of our evacuation routes and trial, shall we say, fire drills that are occurring. If we do mean that our plants are safe, then we should say that they are, but at the same time, I think that we should certainly instill more confidence in the public, so I appreciate your remarks to that concern as well.

Thank you, gentlemen.

Our next panel of witnesses include Dr. Howard Arnold who is general manager of the advanced reactor division of Westinghouse, Mr. R.O. Williams, president of energy systems group of Rockwell International, Dr. Bertram Wolfe of General Electric Co., Dr. Charles Till of Argonne National Laboratory, and Mr. John C. Young who is president of International Energy Associates Limited. We welcome you gentlemen to our hearings this afternoon. We certainly look forward to your testimony.

Dr. Wolfe, I am sorry I had you in the wrong panel, but I am certainly glad you are here.

Dr. **Wolfe.** I am the missing Dr. Wolfe, but I am delighted to be here.

Mrs. **Lloyd.** As I told the previous panel, we do have your complete testimony. You may proceed as you wish and be assured that your entire statement will be made a part of the record.

Dr. Arnold, please proceed.

STATEMENT OF DR. W. HOWARD ARNOLD, GENERAL MANAGER, ADVANCED ENERGY SYSTEMS DIVISION, WESTINGHOUSE ELECTRIC CORP.

Dr. **Arnold.** Thank you, Madam Chairman. Perhaps by virtue of alphabetical order, I am first.

I am Howard Arnold, general manager of the advanced energy systems division of Westinghouse. It is a slight name change because we also have some non-nuclear energy programs in the division.

I joined Westinghouse in 1955 after receiving a Ph. D. in physics from Princeton University. I have been personally involved in technical and management positions in our PWR reactor programs, both domestic and international, our NERVA program for deployment of compact gas reactors for nuclear rockets and our liquid metal reactor development programs. I am a registered professional nuclear engineer in Pennsylvania and a member of the National Academy of Engineering as well as a fellow of the American Nuclear Society.

I am very pleased to have the opportunity to present my views on development directions for power reactors. My prepared testimony did not address reactors for space applications, as I did participate in your hearings this past May, but would be happy to address questions in that area also.

Our involvement in nuclear power development is well known. It is a 35-year legacy from the *Nautilus* submarine reactor through, currently, 83 online nuclear powerplants worldwide. We employ 16,000 people in the nuclear business, over 10,000 of whom are in the commercial aspects. Our water reactor divisions is the largest commercial nuclear organization in the world, having provided or designed 75 percent of the free world's pressurized water reactors, itself the leading reactor type. Our company has also been involved in the forefront of various advanced nuclear concepts such as the liquid metal reactor, LMR, and the compact gas reactor for rocket engines, NERVA. We were also contractor for the U.S. demonstration heavy water pressure tube reactor, CVTR.

Much has been made lately of the idea that to resuscitate the so-called moribund nuclear industry, it is necessary to develop a radically different nuclear powerplant design. Two factors are alluded to as the cause of the industry' malaise: cost and safety.

First, I would like to observe that the industry is not moribund. Our domestic service and fuel business and our international full-scope nuclear business are strong, and we expect them to remain so. We are, however, concerned that the present U.S. lead in the design and systems aspects of this high technology world business will be dissipated without a logical national posture. I agree with Dr. Brewer's remark this morning that we could eventually become a nuclear banana republic.

The current lack of domestic utility interest in new plants is, in my opinion, due to a combination of lack of need for capacity and the high perceived financial risk to the utility that decides to build one. When the need for capacity returns, and it will, even if it is a decade or more away, the utilities must also be able to make a construction decision that is not literally one of "bet the company." This perception is the one that must be removed in the interim.

With regard to cost, it is the higher end of the statistics that we are seeing now that colors everyone's perception. The long-delayed extreme examples are receiving the publicity as are the ones being canceled. Other plants, started as projects at the same time, are now operating successfully. You referred to the Sequoyah plant near Chattanooga. That is only one of many successful examples.

Safety is vital, but here I contend that the issue is not comparative among reactor alternatives. Rather, it is again the ability to predict that a given plant will be licensed without excruciating backfitting and reanalysis, and consequent escalation of cost and schedule. Some recent bad examples of this process could lead to the fear that the end result would always be in doubt no matter what the expense. These cases, I contend, are not a result of absolute safety per se. Very similar plants are safely producing electricity at competitive cost.

Yes, we should work vigorously to address these problems and be ready when our need for capacity returns. Of course, at that point, the most cost effective option may well be to complete some of the now suspended or canceled plants. Thus, it goes without saying that continuing to address current issues, such as licensing reform, is vital.

Beyond that, the picture worldwide supports the contention that the two best developed U.S. reactor types, lightwater reactors, or LWR's, and liquid metal reactors, or LMR's, are excellent contenders on the world market. I believe they should continue to be our highest priority, as any new type that we would begin with now could have no substantial leverage, either domestically or internationally, for literally decades. Our own experience is that an absolute minimum of 15 to 20 years would be required before essentially commercial offerings could be made.

In establishing priorities for new initiatives, the success of the available reactor types must be put into perspective. The best gage of this success can be obtained by observing what has happened and is happening in that same world market. At the present there are 325 lightwater reactors on order, under construction, and in operation in the non-Communist world. Of these, 219 are PWR's, and 106 are BWR's, two variations on the lightwater reactor. Gas-cooled reactors and heavywater reactors together represent a total of 91 plants. Therefore, LWR's have achieved preeminence as the market leaders in a market that has included gas-cooled as well as heavywater reactors. Parenthetically, I would also note that most of the reactors being built in the Soviet bloc are also lightwater reactors, their second choice also being liquid metal.

We at Westinghouse have the most successful record in terms of numbers of reactors. Our technology is used in 75 percent of the 219 PWR's in the world. Westinghouse-designed PWR's represent a total of 165 plants, of which 98 were sold directly by us and 67 sold through licensees in Europe and Japan.

To further illustrate the point, several countries have adopted our PWR technology through licensing agreements, having first started along a different path. The French started with eight gas-cooled reactors. In 1970, they announced Fessenheim, the first of their 55 PWR's of our design. The United Kingdom started with some 40 gas-cooled reactors and are now also switching to Westinghouse PWR technology. Sizewell B, their first PWR, will be built by the Central Electricity Generating Board to our licensed design.

In Japan, who in their early program built a gas reactor imported from the United Kingdom, we and our licensee, Mitsubishi Heavy Industries, have been contracted for 17 PWR plants, of which 14 are in operation, and more continue to be ordered on a steady basis in Japan.

An advanced version of the PWR is being designed in collaboration between ourselves and our licensee, again, Mitsubishi, for early construction. This advanced PWR is designed to produce lower fuel costs while holding the plant costs in line with current powerplants. Along with improved costs, safety aspects have also been improved.

The second choice of the world is for liquid metal reactors. The United States, the United Kingdom, France, the European Community, Japan, and the U.S.S.R. all have and will continue to have very significant liquid metal reactor programs. Originally, the decision of the world to develop LMR's was based on their ability to breed fuel. More recent developments, however, are showing that the LMR may have the capability to be economically competitive with coal and perhaps even lightwater reactors, even if the price of uranium were to remain low. It is also a very attractive design from a safety standpoint, having a low system pressure and a demonstrated capability for natural circulation emergency cooling. The desirable features of low cost, safety, and ability to breed clearly make the LMR the next priority in a balanced program.

By all means, we should perform comparative evaluations of other reactor types. However, there must first be developed a common basis for comparison. Each of the various concepts that has been suggested as alternatives to LWR's and LMR's has features that are desirable.

Ms. LLOYD. Excuse me, Doctor. Can you somewhat summarize the remainder of your remarks?

Dr. ARNOLD. All right. I am very close to the end.

Their proponents naturally do not highlight these weak points, but in the case of both lightwater reactors and liquid metal reactors, both the strengths and weaknesses are generally well known, and improvements are being achieved by evolutionary changes.

I have appended to my testimony a number of suggestions for development directions for both the light-water reactors and liquid metal reactors. I would highlight one point which responds to an earlier question of the previous panel which is the packageability of a smaller reactor design. One of the papers that I have appended to the testimony is a concept and a rather detailed design that we did in conjunction with some Japanese partners on a 600 MW PWR which was factory or shipyard assembled, and we put that in the testimony.

Ms. Lloyd. We will be happy to make that part of the record and we certainly appreciate it and all your testimony, and your complete statement will be in the record.

Dr. Arnold. Thank you, Madam Chairman.

[The prepared statement, plus attachments, of Dr. Arnold follows:]

PREPARED STATEMENT OF DR. W. HOWARD ARNOLD, WESTINGHOUSE ELECTRIC CORP.

MADAM CHAIRMAN, AND MEMBERS OF THE SUBCOMMITTEE,

I am Howard Arnold, General Manager of the Advanced Energy Systems Division of Westinghouse Electric Corporation.

The history of Westinghouse is marked with pioneering achievements in electric power, from the harnessing of the power of Niagara Falls to the commercial application of nuclear power.

Our involvement in nuclear power development is well known...a 35-year legacy rom the Nautilus submarine reactor through 83 on-line nuclear power plants worldwide. Our Water Reactor Divisions is the largest commercial nuclear organization in the world, having provided or designed 75 percent of the free world's pressurized water reactors, itself the leading reactor type. Our company has also been involved in the forefront of various advanced nuclear concepts, such as the liquid metal reactor (LMR) and the compact gas reactor for rocket engines (NERVA). We were also contractor for the U.S. demonstration heavy water pressure tube reactor (CVTR).

We have played the lead role in support of the Department of Energy on the Fast Flux Test Facility (FFTF) and the Clinch River Breeder Reactor Project (CRBRP). At the present time we are actively participating in large plant design studies and the Liquid Metal Fast Breeder Reactor (LMFBR) Base Technology Program at the Advanced Energy Systems Division and the Westinghouse Hanford Company, which operates the Hanford Engineering Development Laboratory for the Department of Energy.

Today, Westinghouse is applying this experience base to the engineering and design of advanced light water reactors, low cost advanced reactor concepts, and compact reactors for space and land-based applications.

I am pleased to have this opportunity to discuss several important issues related to maintaining the nuclear option in the United States...issues crucial to this nation's continued economic growth and national security.

NUCLEAR POWER SITUATION

Much has been made lately of the idea that to resuscitate the so-called moribund nuclear industry, it is necessary to develop a radically different nuclear power plant design. Two factors are alluded to as the cause of the industry's malaise: cost and safety. First, I'd like to observe that the industry is not moribund. Our domestic service and fuel business and our international full-scope nuclear business are strong, and we expect them to remain so. We are, however, concerned that the present U.S. lead in this high-technology world business will be dissipated without a logical national posture.

The current lack of domestic utility interest in new nuclear plants is, in my opinion, due to a combination of lack of need for capacity and the high perceived financial risk to the utility that decides to build one. When the need for capacity returns--and it will, even if it is a decade or more away--the utilities must also be able to make a construction decision that is not literally one of "bet the company." This perception is one that must be removed in the interim.

With regard to cost, it is the higher end of the statistics that we are seeing now that color everyone's perception. The long-delayed extreme examples are receiving the publicity. Other plants, started as projects at the same time, are now operating successfully. Although absolute cost reduction should, and is being, pursued vigorously, I contend that the ability to predict that a plant will finally cost close to a given figure is a necessity for a decision to proceed.

Safety is also vital, but here I contend that the issue is not comparative safety among reactor alternatives. Rather, it is again the ability to predict that a given plant will be licensed without excruciating backfitting and re-analysis and consequent escalation of cost and schedule. Some recent bad examples of this process could lead to a fear that the end result could be in doubt, no matter what the expense. These cases are not a result of absolute safety per se--very similar plants are safely producing electricity at competitive cost.

Yes, we should work vigorously to address these problems and be ready when our need for capacity returns. Of course, the most cost-effective option when that happens may well be to complete some of the now suspended or cancelled plants. Thus, it goes without saying that continuing to address current issues, such as licensing reform, is vital. Beyond that, the picture world-wide supports the contention that the two best developed U.S. reactor types--light water (LWR) and liquid metal (LMR)--are excellent contenders on the world market. I believe that they should continue to be our highest priority, as any new type that we would begin with now could have no substantial leverage, either domestically or internationally, for literally decades. Our experience is that an absolute minimum of 15 to 20 years would be required before essentially commercial offerings could be made of a new reactor type we would begin now.

Thus, I think the utility problems related to predictability of acceptable cost and licensability should be addressed in the order of priority of LWR's first, LMR's second. LWR's can be built to levels of acceptable cost and safety, as demonstrated by the 183 now in operation world-wide. Further work can be most useful, however, in improving cost and further reducing risk levels. LMR's can be built with acceptable safety, as attested to by the ten now in operation with more than 140 reactor years of operating experience, and the successful conclusion of the Clinch River licensing hearings for the construction permit. The long-range promise of this reactor type continues to justify a major program addressed to reducing costs and risks.

PRIORITIES FOR NEW INITIATIVES

In establishing priorities for new initiatives, the success of the available reactor types must be put into perspective. The best gauge of this success can be obtained by observing what has happened, and is happening, in the world market. Within the United States and throughout the world, a general consensus has been reached on the most desirable reactor types that must be considered in any meaningful planning for new initiatives. These are the light water reactor now and, for the future, the liquid metal reactor. The only other reactor type to obtain any sustained market penetration is the heavy water reactor (HWR). Other types, such as the gas-cooled reactor (GCR), were deployed, but did not succeed in the real measure of the competitive market.

To better illustrate this point, at the present there are 325 light water reactors on order, under construction, and in operation in the non-Communist world. Of these, 219 are PWR's, and 106 are BWR's. Gas-cooled reactors and heavy water reactors together represent a total of 91 plants. Therefore, LWR's have achieved pre-eminence as the market leaders in a market that has included gas-cooled as well as heavy water reactors.

Westinghouse is the most successful and experienced of the world's pressurized water reactor vendors. Westinghouse technology is used in approximately 75 percent of the 219 PWR's in the world. Westinghouse-designed PWR's represent a total of 165 plants, of which 98 PWR's were sold directly, and 67 PWR's were sold through licensees in Europe and Japan.

To further illustrate the point, several countries have adopted the Westinghouse PWR technology through licensing agreements, having first started along a different path. The French started with eight gas-cooled reactors. In 1970, the French announced Fessenheim, the first of 55 PWR's of Westinghouse design. Framatome still has a technology agreement with Westinghouse that will extend through 1992. The United Kingdom started with some 40 gas-cooled reactors and are now also switching to Westinghouse PWR technology. Sizewell B, their first PWR, will be built by the Central Electricity Generating Board (CEGB) to our licensed design.

Advanced versions of both the PWR and boiling water reactor (BWR) are being designed in collaboration with industrial counterparts in Japan for early construction. The advanced PWR is designed to produce lower fuel costs while holding the plant costs in line with current power plants. Along with improved costs, safety aspects have also been improved. An additional endorsement of light water reactors is the United States' application of over 100 light water reactor plants for demanding military, marine propulsion service. Clearly, a balanced program must recognize that the first choice of the world for nuclear power is the light water reactor.

Similarly, the second choice of the world is for liquid metal reactors. The United States, England, France, the European community, Japan, and Russia, all have and will continue to have very significant LMR programs. Originally, the decision of the world to develop LMR's was based on their ability to breed fuel. More recent developments, however, are showing that the LMR may have the capability to be economically competitive with coal (and perhaps even LWR's), even if the price of uranium remains low. It is also a very attractive design from a safety standpoint, having a low system pressure and a capability for natural circulation emergency cooling. The desirable features of low cost, safety, and ability to breed clearly make the LMR the second priority in a balanced program.

To maintain a balanced program for the new initiative, we recommend that priority be given to the continued improvement of LWR's. Almost all of the R&D activities are already being supported by industry. Additional support by DOE could greatly augment this necessary activity, lead more quickly to a still better result, and support a very important U.S. export product.

The next priority is to continue the development of the LMR's. This represents a greater requirement for funding because some R&D costs remain for long-term LMR product development. The activities that should be pursued must reduce financial and licensing risks. Successful completion of these activities, which are already well along, will assure the United States of a low cost, safe energy supply for the long-range future. This reactor type remains pre-eminent in its ability to use less of our uranium resource.

By all means, we should perform comparative evaluations of other reactor types. However, there must first be developed a common basis for comparison. Each of the various concepts that has been suggested as alternatives to LWR's and LMR's has features that are desirable. However, their proponents naturally do not highlight their weak points. In the case of LWR's and LMR's, both the strengths and weaknesses are generally well known, and improvements are being achieved by evolutionary changes.

The alternative conceptual designs should be compared to LWR's and LMR's, using a set of acceptance criteria, such as cost and schedule for development, cost and schedule to construct, marketplace acceptance, construction schedule, and licensing risks, and some agreed-upon method of evaluating comparative safety.

This won't be easy, but without such an approach, it is impossible to compare "blue sky" concepts with well developed reactor types. We further recommend that the Nuclear Regulatory Commission be involved in the comparative evaluation of alternative concepts. If a truly superior alternative concept emerges from such efforts, then, and only then, should it be considered for substantial development. Going into substantial development prior to an objective evaluation would be wasteful. Furthermore, it would allow our international competitors to gain an advantage through evolutionary improvements of the two major reactor types, whose development would be slowed in the United States by diversion of program funding.

DIRECTIONS FOR DEVELOPMENT

Over the last two years, Westinghouse has been involved in a review of its advanced PWR with eight leading U. S. nuclear utilities. We believe the directions for development of any reactor type can be inferred from what the utilities told us in these reviews. The utilities want a more certain future, both in a financial and licensing sense. They want, above all, a proven, tested design with the bugs worked out, a design that reduces up-front capital cost and lessens risk to shareholders and rate-shocked customers. We believe this means that we should make "the good" even better. We should work on the most proven reactor types to make them much less sensitive to financial risks. The solution will involve licensing reforms, packaging for assured construction schedules and ease of licensing, and improved safety, especially to the extent that it reduces the risk of licensing delays. I will make specific suggestions for both LWR and LMR development programs.

Westinghouse and its Licensee Mitsubishi Heavy Industries (MHI) have been in the process of developing an advanced pressurized water reactor (APWR) for six years. This advanced design deals head-on with the issues affecting acceptability by a utility. These are:

- Reduced mills per kilowatt hour to the customer
- Improved operational characteristics
- Increased investment protection in the event of a significant accident
- Enhanced public safety

During the course of the new design activities, it was found that solutions to several of the objectives are complementary. This is not always the case when existing hardware must be modified to meet changing requirements. This program is an example of development leading to a superior reactor plant supported by industry. Further information on this reactor concept is appended to this testimony.

Another plant concept that is being developed, and would benefit from DOE support, is the NUPACK (nuclear packages). This Westinghouse concept is a significant development that offers the potential for a cost-effective application of nuclear power through modularization. The basic plant is a 600-MWe unit using conventional proven systems and equipment but arranged into several barge-type packages for erection and pretesting in standard, existing shipyards. The expected result will be a power plant design with predictable cost and schedule along with other benefits, including ease of licensing, improved quality, and utilization of otherwise unusable sites. A paper more fully describing this concept is appended to this testimony.

Smaller nuclear power plants may have some merit relative to reducing the financial risks to utilities. The Westinghouse 2LN is a two-loop nuclear unit with a power rating of 655MWe that has been developed on the basis of the Westinghouse PWR modular design provided with two coolant loops. This design for a small nuclear power plant is unique in that it has been developed as the result of over 15 years of systematic upgrading of the already mature design utilized in the twin-unit Beznau nuclear power plant. The Beznau plant, located in Dottingen, Switzerland, has an outstanding operating record.

The eight 2LN units now in operation or in advanced stages of construction provide extensive verification of the design in a wide range of site conditions. Some of the plants are located in the United States, and others are overseas; some are in highly developed countries, and others are in emerging countries; some are cooled by salt water and others by fresh water or cooling towers; some are generating at 60 Hz and others at 50 Hz. The plants use a wide variety of local material and components, and the design has been implemented in high seismic areas.

Other examples of programs for which DOE support would greatly enhance the quality of LWR's include quality assurance improvements, nuclear plant standardization programs, and design and construction simplification. These three items are particularly suited to implementation by DOE. A paper more fully describing these development needs is appended to this testimony.

As mentioned earlier, the second priority should be the LMR. The objective of the LMR program should be directed to using the investment already made in LMR technology in a manner that will lead to a proven and tested LMR plant. This can be accomplished by focusing the program to preserve its strengths and undertaking new initiatives to fill the voids left by the termination of the Clinch River Breeder Reactor Plant.

The first key element of a focused LMR program is a strong base technology program. Continued operation of the Fast Flux Test Facility (FFTF) and Experimental Breeder Reactor (EBR) II will provide valuable reactor performance and operating experience in addition to the development data derived from testing of components and systems in these plants. Development and testing of the technologies required to close the breeder fuel cycle are also essential and can be accomplished by completing and operating the Secure Automated Fabrication (SAF) line and the Breeder Reprocessing Engineering Test (BRET). Further development of low cost, inherently safe LMR designs, and the components used in these designs, is another key part of maintaining a strong base technology program. In this regard, Westinghouse started the development of a low cost, inherently safe LMR about four years ago.

This activity has been partially supported for the last two years by DOE. Like the NUPACK, it has been found that modifications to conventional LMR designs are possible that significantly improve plant costs, safety, and reliability. LMR costs can be reduced to a level competitive with current commercial coal (and perhaps even LWR's) through a new design approach featuring a uniquely compact and simplified arrangement of shop-fabricated plant modules and an integrated fuel processing facility. The integrated fuel facility closes the fuel cycle within the nuclear plant itself. This approach economizes on construction commodities and labor and will greatly improve construction schedules--all of which translate to lower costs and less financial risk. It also ensures a secure and reliable fuel supply at a cost that improves upon coal and LWR fuel costs. Further, a maximum use of inherent safety features in LMR design can provide an eminently safe and reliable plant at low cost. In short, a cost-effective, safer, and technically superior LMR can be designed now that will provide a firm and practical base for an LMR industry for the future. A listing of development activities that support the low cost LMR plant is appended to this testimony.

The second element of a focused program is enhanced international cooperation. Our program strengths lie in our technology and component development while programs overseas have strong demonstration plant projects. If we can arrange for meaningful utilization of our components and our technologies in overseas programs, we can confirm the performance of these technologies and components while gaining experience in construction, operation, and maintenance of LMR's. The CRBRP components offer us the unique opportunity to accomplish this element at low cost.

The third element involves confirming state-of-the-art systems and components, including their operability and maintainability, by modifying FFTF to produce electricity. The availability of CRBRP components offers us the opportunity to modify FFTF to provide a valuable component test facility while maintaining it as a reactor test facility. Confirmation of steam generator design, manufacture, installation, operation, and maintenance in a power plant environment is essential to development of LMR's. This can readily be accomplished in the modified FFTF facility. The operation of other LMR components and advanced breeder cores can also be proven in the modified facility. The cost of this project can be offset by providing electricity for Hanford.

The fourth element, verification of the licensability of LMR's, is essential to both industry and the utilities. The recently issued findings of NRC's Atomic Safety and Licensing Board demonstrated the licensability of CRBRP relative to construction. This result will serve as a benchmark for all future LMR's. Continued interaction with NRC, through review of the evolving low cost, inherently safe LMR plant designs, will extend the verification to these designs.

The final essential element of a focused LMR program is preservation of the ability to accomplish future plant designs by documenting CRBRP key data and experience and completing certain key tests. Because of the nearly completed efforts in many high-cost development areas, and the generic value of the results, this element will provide valuable results at low cost. The results will also support new initiatives involving use of CRBRP components as well as contribute significantly to the strength of our base technology program. Further discussion on these five key elements of focus for the future LMR program is appended to this testimony.

In conclusion, I believe the United States should devote the bulk of its limited reactor development resources to the highest priority projects--the LWR, which is already pre-eminent in the world market, and the LMR, which is the advanced reactor of choice among developed nations. The LWR effort would not involve substantial development funds, but does need government support on a policy basis along with some specially targeted development. The LMR needs continuity in the efforts under way to safeguard an investment that keeps us among the leaders in this type. Other reactor types should be the subjects of rigorous comparisons, but commitment to substantial development would be at the expense of higher priority efforts.

Attachments:
1. Enhancing the Utility Nuclear Investment (Through an Advanced PWR)
2. Application of Modular Plant Design (to the PWR)
3. Suggestions for LWR Development
4. Suggestions for LMR Development
5. Suggestions for U.S. LMFBR program Direction

W. Howard Arnold
General Manager
Advanced Energy Systems Division

Dr. Arnold heads the Division of Westinghouse responsible for development of both advanced nuclear reactors and alternative energy sources. This Division, along with the Westinghouse Hanford Company, the Westinghouse Idaho Nuclear Company, and the Waste Technology Services Division, is in turn part of the Advanced Power Systems business unit. The major programs currently under way in Dr. Arnold's Division are development work for breeder reactors, nuclear reactors for defense applications other than naval propulsion, fuel cell terrestrial power plants, solar photovoltaic power modules, electrical wind turbine systems, and MHD and other emerging energy technologies.

Prior to his current assignment, Dr. Arnold's career has involved a broad range of technical and management responsibili- ties in the energy and defense fields. He was associated with the NERVA nuclear rocket program from 1962 to 1968, directly responsible for test operations in Nevada during four successful tests, and then became NERVA program manager. In the Westinghouse Defense Center, he was Manager, Underseas Weapons Department, from 1968-71, when the development of the Mk48 torpedo, current main- stay of the fleet, was successfully completed. Associated with Westinghouse commercial pressurized water reactor power plants from 1955-61 and from 1971-81, he became General Manager, PWR Systems Division in 1972, and President, Westinghouse Nuclear International, in 1979. In these positions, he was responsible for the design, nuclear safety, and project management of 98 Westinghouse PWR nuclear steam supply systems and for technical support of an additional 66 built by Westinghouse licensees. In 1981, he became General Manager of the Advanced Reactors Division which was combined with the alternative energy operations in 1983 to become the Advanced Energy Systems Division.

Dr. Arnold joined Westinghouse in 1955 as a senior engineer in reactor design after earning a Doctorate and Masters degrees in physics at Princeton University, and his Bachelor's degree in physics and chemistry at Cornell University in 1951. He was elected to the National Academy of Engineering in 1974, is a registered nuclear engineer in Pennsylvania, and a Fellow of the American Nuclear Society and the American Association for the Advancement of Science. He was born at Jefferson Barracks, Missouri, in 1931, and married Josephine Routheau in 1952. They live in Pittsburgh, where they have raised five children.

ENHANCING THE UTILITY NUCLEAR INVESTMENT

C. K. Paulson
Manager, Plant & Integrated Systems
Westinghouse Electric Corporation
Pittsburgh, Pennsylvania

INTRODUCTION

After seven years without a new plant order in the United States, a number of clear objectives have come into focus on the needs for future nuclear power plants and what must be changed to increase the potential for ordering these plants. Future investments by utilities in nuclear units require the following minimum list of considerations be addressed:

- Reduced mills per kilowatt hours to the consumer.
- Enhanced public safety.
- Improved plant operational characteristics.
- Increased investment protection in the event of a significant accident.

Westinghouse has been in the process of developing an Advanced Pressurized Water Reactor (APWR) for six years. This advanced design deals head-on with the issues identified above. The program has been enhanced by the participation of the Westinghouse licensee, Mitsubishi, and now major efforts by both Westinghouse and Mitsubishi are leading to a design that focuses on the next generation of nuclear units.

An unusual phenomena, at least in the nuclear business, has occurred in this design when addressing the design objectives. Solutions to several of the objectives are complementary rather than mutually exclusive. This has not been the case when old designs are "patched up" to meet new requirements. An example of this effect occurs in the Safeguards Systems design that has led to both a more simple design that reduces the utility risk if an abnormal event were to occur and also enhances protection of the public.

DISCUSSION

Reduced Electrical Rates to the Consumer

Less inflationary electrical rates to the consumer have been characteristic of nuclear power. These cost savings continue to be proven throughout the United States (and around the world). However, additional savings in electrical costs have accrued due to changes in the fuel/core design of the Westinghouse Advanced Pressurized Water Reactor. These changes include:

- A reduced power density core with reduced Separative Work requirements, and more safety/operational margins.

- A design feature that appears very promising, moderator control. This feature displaces approximately 15% of the core coolant, thereby hardening the neutron spectrum and increasing the fissile Plutonium production in the core that is burned later in the fuel cycle. These changes will have a significant impact on cost of electricity to the user because of the significant fuel cycle savings.

Other activities that will ultimately reduce electrical costs to the consumer deals with pre-construction design information and licensing. Three specific points are significant. These are:

- A significant cost increase in the past on nuclear power plant projects has been the lack of a complete design at the time of construction initiation. Although many plant designs now have a high degree of completion, these designs are 10 or more years old and therefore represent a decade-old technology that has attempted to address new codes, standards and regulatory requirements. The APWR will not only take into account these design perturbations, but will incorporate them in an integrated way into the overall plant design instead of the "patch work quilt" approach that has been necessary in older designs.

  The APWR plant design will also be approximately 70% complete before construction begins. This degree of completion allows the utility to incorporate some idiosyncrasies, however they will not significantly impact bill of materials, construction schedules, and system designs.

- As part of the design process, significant simplifications are being introduced so that construction and erection schedules can be further reduced. Examples of design simplification incorporated in the APWR include:
  - Elimination of cross-over lines in the Safety Injection System, thereby significantly reducing piping complexities.
  - Elimination of RTD Bypass Manifold and associated piping and valves.
  - A non safety grade startup feedwater system.
- Westinghouse is currently providing to the NRC system designs modules of the APWR for review to enhance licensability of the next generation of nuclear plants. This review is being supported by the NRC staff.

Enhanced Public Safety

Several key plant modifications have been incorporated into the Westinghouse APWR design to enhance public safety. These features are discussed below.

- The potential for releases of primary grade water outside the containment and to the environment is reduced by containing the pipe and components in high pressure barriers, thereby reducing a key contributor to offsite doses.

- The potential for core melt and the consequential risk to the public has been reduced by more than one order of magnitude by incorporating the reduced power density core and also by providing significantly more primary system coolant in the vessel above the core. This configuration is shown in Figure 1.

- Reliability improvements in both the primary safeguard system and emergency feedwater system cooling functions have also lead to significant improvements in core cooling assurance. This is accomplished by increasing the number of available pumps, but reducing the capacity of each pump thereby maintaining cost effectiveness in the overall design.

Improved Plant Operational Characteristics

Reliability and maintainability of the plant have been key objectives since the start of the design process. Both lead to improved plant availability. Some of the design features that will help meet these objectives include:

- 18 month fuel cycle (with a potential for going to 24 months). This extended fuel cycle has both economic and availability benefits.

- A steam generator designed for significantly improved access so that any maintenance can be done quickly and efficiently, with minimal radiation exposure to operating personnel. Also, the steam generator materials have been chosen to enhance corrosion resistance.

- Overall plant layout improvements are incorporated into the design to minimize maintenance and repair time by guaranteeing easy access.

- Reliability Engineering of components and systems is being utilized to enhance performance of the plant.

The above design considerations are being pursued to meet the ultimate objective of 90% plant availability.

A key aspect of the program to improve operational performance that has had significant attention is reducing Operational Radiation Exposure (ORE). Design features that address this area include:

- Materials selection especially utilizing materials with reduced cobalt impurities (0.015 wt. %) and reduced sludge-forming characteristics.

- Equipment shielding where radioactive components cause maintenance problems.

- High primary and secondary system water coolant purity to reduce the potential for corrosion product formation.

- Extended fuel cycles.

The objective of this program is 100 man-rem per year ORE.

Protecting the Utility Investment

As identified earlier in the paper, enhancing public safety has also led to an improved design from the perspective of utility investment protection. Some plant features that have been incorporated in the Westinghouse APWR design would reduce costs a utility may experience if a significant plant accident were to occur. Specific areas where enhanced utility investment protection are addressed include:

- The reduced power density core. This feature in combination with primary loop configuration modifications have led to the elimination of core uncovery during small loss of coolant accidents. If I had to identify the most probable concern of a utility executive, my vote would go for the small pipe break causing fuel damage. The APWR design essentially eliminates that concern.

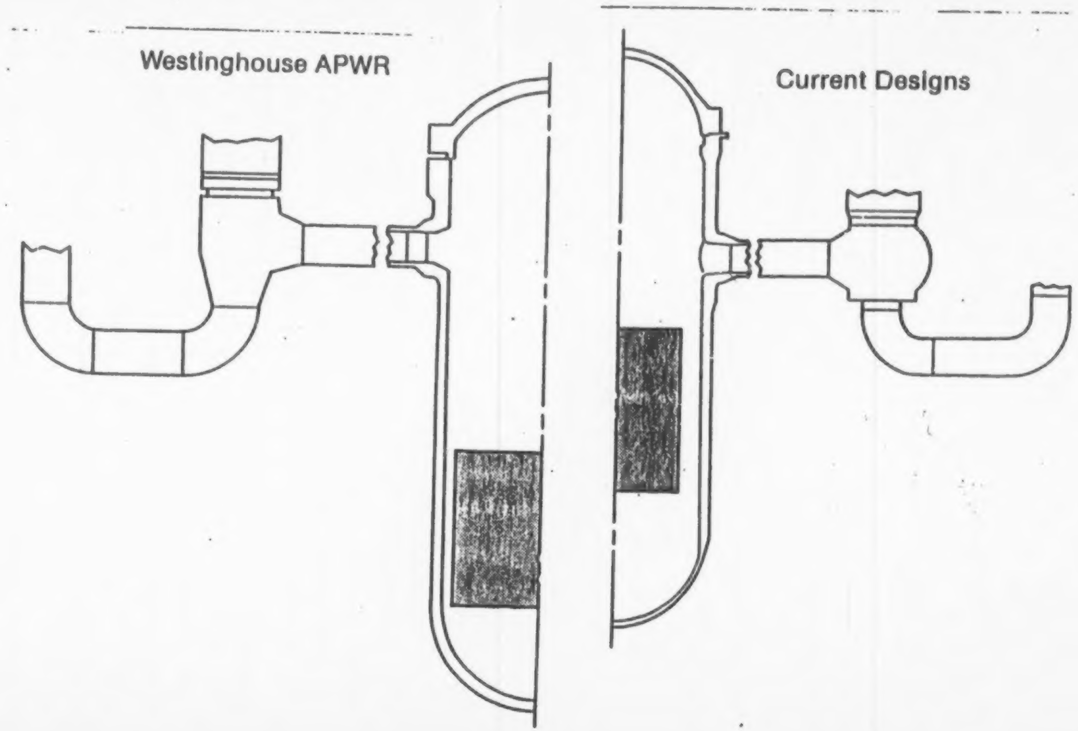
- Control of primary system fluids in a manner that reduces containment contamination. The design feature directs primary system water into controlled areas within containment if a pipe break is experienced and the Safety Injection System continues to perform. This design feature significantly reduces any cleanup that would be required after an accident.

- Design features for diverse core cooling that meet safety requirements. These features virtually guarantee core cooling capability even if primary safeguards systems are assumed inoperable.

CONCLUSION

Many features are included in the Advanced PWR design that significantly enhance the utility investment. The benefits incorporated into this PWR could not be accomplished in current plant designs without significant configuration modifications. Westinghouse believes this design addresses the key issues of nuclear power plant designs required for the next generation of reactors.

FIGURE 1
LOOP CONFIGURATION COMPARISON


Westinghouse APWR
Current Designs

APPLICATION OF MODULAR PLANT DESIGN

J. A. Dahlheimer Westinghouse Electric Corporation, Pittsburgh, USA
H. E. Braun Westinghouse Electric Corporation, Pittsburgh, USA
Dr. K. Fujita Hazama-Gumi Ltd., Tokyo, Japan

INTRODUCTION

The suitability of nuclear power plants for the electrical generating grid of any country depends on a number of complex technical, political and economic factors. In the technical and economic areas, two of the more important requirements are: 1) the existence of a developed infrastructure capable of undertaking the construction of the plant within cost and schedule limits; and 2) the availability of suitable sites for plant construction.

Nuclear power plants are among the most advanced and complex industrial facilities being built today requiring the services of thousands of technical personnel and many thousands of non-technical workers over many years. In almost every area these plants incorporate the current state of the technical arts. The very latest design and analysis techniques are used for systems, equipment and structures. But there is a major exception to this use of creative and new methods. In the area of plant construction, the basic approach is fundamentally unchanged from that employed by builders for centuries. A large number of workers are recruited, relocated to an often remote site, trained with great effort during the course of the project, coordinated to construct the project with materials collected from various suppliers and then, when the one-of-a-kind project is complete, dispersed to other locations to work on other types of projects.

Without even considering the complexity of the actual construction effort, the logistics of a nuclear job may be overwhelming, particularly when the site is remote from labor centers, as it may be for a nuclear unit, or when the numbers and technical skills of the available local work force are below the required levels as will most likely be the situation in all but larger industrial countries.

Thus even with the usage of modern equipment for lifting, pouring concrete and other tasks, the ability to accomplish difficult construction projects remains largely an acquired skill or art that cannot readily be transferred or sold as can equipment or a plant design.

As a consequence many countries or regions that could otherwise benefit from the application of nuclear power are discouraged from doing so due to the cost and schedule uncertainties inherent in such a complex task. This is particularly true when the power growth rate of the country is such that there is only a near term need for a single unit rather than the series of units which would provide the rationale for undertaking the difficult nuclear learning process and establishing the construction infrastructure.

Even when all of the needed organizational, technical and labor skills are present in abundance and of the highest quality, and when the need for power is well established, the ability to apply the nuclear option still depends on the availability of suitable sites. An unfortunate dilemma for some countries, most notably Japan, is that even though the need for nuclear power is there and the ability to build the plants is impressively established, the time may be near when regions of the country will simply run out of sites.

Westinghouse is now developing an innovative design which should significantly improve the attractiveness of the nuclear option in a number of countries by removing from the field the most complex and difficult parts of the plant construction effort. This will improve the certainty of cost and schedule, reduce site impacts, minimize the needed nuclear infrastructure and provide flexibility for load growth planning. An innovative application of this concept proposed by and being jointly developed with Hazama-Gumi could indirectly increase the number of available plant sites in certain regions of Japan by making use of mountainous areas on the coasts.

In simplest terms, the concept utilizes a plant design suitable for fabrication as several large modules. This allows the complex technical and administrative activities related to assembly and installation of the systems and hardware to be transferred from a remote site to an industrial setting where a skilled and stable work force is readily available. On completion of testing the modules are water transported to the site where the mostly civil type of site work would have been accomplished on a parallel schedule rather than a series schedule which is the usual case. The amount and difficulty of the remaining site work is of course dependent on the type of site. The modules are then installed and interconnected to complete the plant.

The design limits the number of interconnections and thus only a small work force of skilled mechanical and electrical labor will be needed to complete the installation and provide any necessary assistance during final testing of the completed plant and subsequent startup.

While the concept was developed by Westinghouse for use with conventional types of ocean or river sites, it was recognized by Hazama-Gumi that NUPACK could be combined with experience based tunneling technology to utilize sites in mountainous locations bordering the ocean.

NUPACK DESIGN

The concept design, identified as NUPACK for Nuclear Packages, is a 600 MWe nuclear plant using conventional proven systems and equipment, but arranged into several barge type packages for fabrication and pretesting in standard, existing shipyards.

The plant packages are integrated, enclosed steel structures similar to barges in that they are watertight and will float. They are not designed to be sea going, but instead are intended to be delivered to the site on transporter barges. This method of delivery allows significant economies in fabrication of the barges since they are not exposed to the high stresses and loads that would be associated with worst case sea conditions.

In the NUPACK design, the number of barge packages utilized will be somewhat dependent on the site and, of course, the utility's preferences. Generally, it is expected that four modules will be used. They are as follows:

- Reactor Barge Package

This barge package incorporates the reactor containment housing the Reactor Coolant System (RCS), the reactor safeguards systems, including emergency diesels, and reactor auxiliary systems such as the Residual Heat Removal (RHR) System, Chemical and Volume Control System (CVCS), the Boron Thermal Regeneration System (BTRS) and the Auxiliary Feedwater System (AFWS). Related electrical systems are also incorporated into this barge package.

Within the containment enclosure is the reactor refueling system and fuel transfer system for new and spent fuel transfer to the fuel building.

The placement of all these systems and their power supplies in the reactor barge package minimizes the need for interconnections of fluid, electrical and instrumentation systems to other barge packages.

The design is illustrated by the various views of the reactor barge package shown in Figure 1, 2, and 3.

Figure 1 - A 600 MWe Reactor Package (Profile)
Figure 2 - Reactor Package (Containment Cross Section)
Figure 3 - Reactor Package NSSS (Containment Plan)

It should be noted that to achieve a relatively narrow package design, the containment is a horizontal, internally reinforced steel cylinder, positioned axial to the package hull (Figure 1). The reactor auxiliary systems, control room and support facilities are located in structures which occupy the package hull at both ends. This provides a degree of design and the weight symmetry required to achieve the necessary floating stability for placement on the transporter barge and movement at the site. Concrete placement, including the three foot thick containment exterior enclosure, is done after grounding the package on the pre-prepared basemat at the site.

- Reactor Auxiliary Barge Package

  This package includes nuclear related systems of a less significant nature as well as support facilities. Systems include waste processing, boron recycle, reactor makeup water and such. Facilities located in this package include machine shop, health physics, and chemistry laboratories.

- Turbine Generator Barge Package

  This barge package contains the main turbine generator and moisture separator reheaters, feedwater heaters, main condensers, circulating water system connections, bus ducts and generator breakers. The barge package also has the plant main control room with both reactor and secondary plant controls.

  The combination of main turbine-generator and its systems with the plant electrical generation - auxiliary power distribution capability and the plant main control room provides a maximum of systems, power and control integration in the same barge package.

- Turbine Generator Auxiliary Barge Package

  This barge package has all the remainder of Balance of Plant systems and equipment including service water system, chemical control, demineralizers and the plant non-radioactive facilities, for example: instrumentation shop, the non-radioactive machine shop and plant stores. It also has the component cooling water heat exchangers (CCW). The top deck of this barge may be used for additional turbine maintenance lay down space.

The principal site constructed facilities include the basins and foundation slabs for the barge packages, main transformer pads and distribution switchyard, security related buildings and the fuel storage building. While the fuel storage building could be prepared as a barge package, it is expected that it will be conventionally built since much of its volume is, empty space with only limited mechanical and electrical systems.

The building is connected to the reactor barge package by a canal or tunnel through which the fuel transfer occurs by means of the fuel transfer system. The fuel building design will be very similar to that of plants now in operation.

The designs and equipment for the nuclear steam supply system, safeguards and other safety related systems are generally adapted from Westinghouse's Floating Nuclear Plant (FNP) design which recently received a US Nuclear Regulatory Commission manufacturing license. The FNP design is however physically much different in that it is a complete 1100 MWe nuclear plant integrated into a single floating package for assembly line fabrication at a very specialized shipyard facility. The dimensions of the package are quite large (400 ft. x 400 ft. x 150 ft. above water), as is the resulting draft (45 ft.). The basic soundness of its technology was verified by the US NRC's extensive review of the design which proceeded issuance of the manufacturing license.

DELIVERY

The NUPACK plant is water delivered and floated into position. Sites are therefore limited to coastal and riverine locations where sufficient depth, about 4 meters, is available or can be made available by dredging. For river sites, additional restrictions may occur due to bridges, locks, or other clearance limiting structures on the river, but since the NUPACK modules are relatively small, the number of potential sites is principally limited by draft. As an example, a study of the Mississippi/Missouri river system in the United States showed that sites some 2000 km from the ocean could be reached with NUPACK. The ocean portion of any delivery voyage will be accomplished with a transporter barge of a type that has been used to deliver other industrial floating modules. For a river site, a substantial part of the trip may be with the module afloat since draft or other clearances may restrict the transporter barge.

SURFACE APPLICATION

A conceptual design for a river site is shown in Figures 4 and 5. Figure 5 shows the basic scheme for the installation within an embankment to provide protection from flooding. Also of note is the use in this instance of only three NUPACK barge packages combined with several conventionally built structures including the turbine auxiliary building and cooling towers.

WHG APPLICATION

A particularly creative siting application is installation of NUPACK into large caverns excavated in sea side cliffs or mountains. This specific application, identified as WHG, for Westinghouse/Hazama-Gumi, is illustrated in Figure 6. The particular merit of the WHG is that it can use rugged sites that would otherwise not be practicable for any type of power plant, nuclear or fossil. This is expected to be of particular importance for certain regions of Japan where conventional sites may not be available in the future due to both the scarcity and high value of the relatively flat coastal land needed for a conventional plant design.

The WHG design consists of two long caverns into which four NUPACK barge packages are installed, a smaller cavern for use as the fuel storage building, a number of interconnecting tunnels for construction and operating access, and a small number of conventionaly built structures outside the caverns and tunnels.

Layout of the caverns and tunnels is readily inferred from Figure 6. One cavern is used for the nuclear barge packages and the second for the turbine generator barge package and its auxiliaries. Several tunnels connect the caverns to provide for routing of steam, feedwater and auxiliary systems piping as well as electrical power and instrumentation cables. A larger tunnel is built between the nuclear cavern and fuel storage cavern to provide for both fuel transfer and major equipment removal and replacement if necessary. Tunnels for circulating water intake and discharge connect to the turbine generator cavern. The ventilation system includes intake and discharge ducts to a suitable point well above the ocean.

As could be expected, the stability of the caverns and tunnels for all conditions, including seismic events, is of the utmost importance. A considerable amount of preliminary analysis has been done based on construction experience in Japan in order to establish the bases for assuring cavern and tunnel stability. Severe criteria will be developed for the initial site selection process and the verification program of testing and analysis. For the WHG application there are compromises or trade offs between the sizes of the barge packages and caverns. Generally, a larger width is desireable for the barge packages to facilitate construction and operating maintenance whereas a smaller cavern width simplifies site selection and verification since cavern stability increases as width decreases. Preliminary work indicates that a barge package width of some 30 meters will allow a good plant layout while not requiring an excessive extrapolation from cavern sizes currently under construction. A comparison of the WHG cavern and tunnel cross sections is shown in Figure 7.

The main caverns are spaced apart a distance set by rock reinforcement and stability requirements. This is expected to approximate twice the cavern width. As shown in Figure 8 the length of the caverns is established not only by the overall end to end totals of the barge packages but also by the slope of the mountain face and, of course, rock stability. It should be noted that the caverns are not exposed to any accident environment since the reactor containment is provided as part of the reactor barge package.

INSTALLATION

Installation on conventional sites requires excavation of the plant area for placement of the base mats, construction of the conventional structures and dredging of the basins to allow floating of the packages on to the base mats. After all the barge packages are in approximate position, the basin is closed. Final barge package positions are set and the basin is dewatered to settle the packages on their base mats. The packages are anchored firmly, required concrete and grout are placed, the packages are interconnected and final testing is performed before fuel loading. Startup and plant operation follow conventional practice.

For the WHG application, the excavation of the caverns and tunnels, any necessary strengthening of the walls or ceilings with rock or rock anchors, preparation of the base mats and all other cavern or tunnel work is done before the opening to the sea is made. The transporter barge arrives and in a calm sea unloads the NUPACK module which is then drawn into its cavern. After arrival and installation of the second package, a temporary cofferdam is installed. The packages are positioned in place, the caverns are dewatered while being rinsed with clear water, to settle the packages for anchoring to the base mats. If needed, the temporary cofferdam is erected between barge package deliveries. The cavern is then permanently sealed with a three meter thick concrete plug. The cavern length between the concrete plug and barge packages is filled with rubble from the excavation. Placement of concrete, interconnection of the barge packages and other finishing work then occurs followed by final testing.

BENEFITS

There are a number of important benefits which would derive directly from the use of shipyard manufacture.

- Increased certainty in cost and schedule - The greater continuity of management and labor, the permanent provision of facilities, the familiarity with modern fabrication techniques and the learning process from an assembly line type of production will all enhance productivity cost control and schedule control. Shorter schedules should be possible.

- Reduced site impact - Conventional construction methods require work forces in the several thousands. When the site is remote, this work force and their families must be housed and provided for during the construction period of 6 or more years. The related physical and social impacts can be very disruptive at both the beginning and end of the project. Additionally, there are the necessary roads and other transportation links needed for heavy loads of equipment and large numbers of people over a short time period.

- Predictable quality - Manufacture of almost any complex product on a production basis using an established and skilled labor force should result in a higher intrinsic level of quality. Also, manufacture in a shipyard affords the opportunity to utilize specialized facilities in a more comprehensive checking and testing program than is feasible at a temporary construction site.

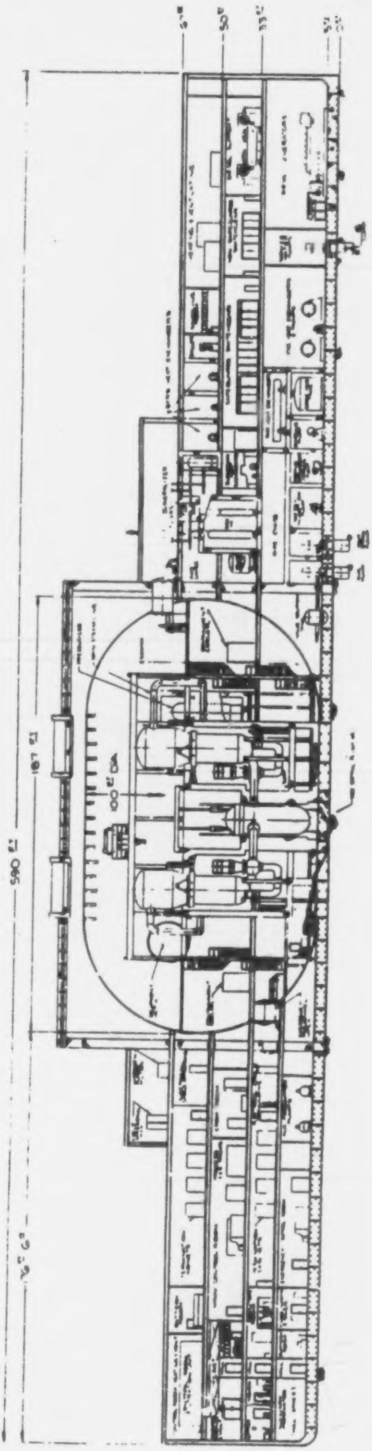
- Flexibility - Long plant construction lead times require utilities to order plants years before the load capacity is needed. If predicted load growth rates change after construction starts, the NUPACK plant can be readily reassigned to another site, another utility or possibly another country. The site can simply be held for the future when load growth resumes.

In addition to these direct benefits the WHG application offers for Japan and possibly other countries the potential for the utilization of otherwise unuseable mountainous sites. While these sites could presumably be used by employing a conventional method of underground installation - where the structures, systems and equipment are installed piece by piece after excavation of the caverns - these methods unavoidably entail considerably higher costs and longer schedule times. Such a method places cavern excavation and plant fabrication in series rather than in parallel, as with the WHG concept.

SUMMARY

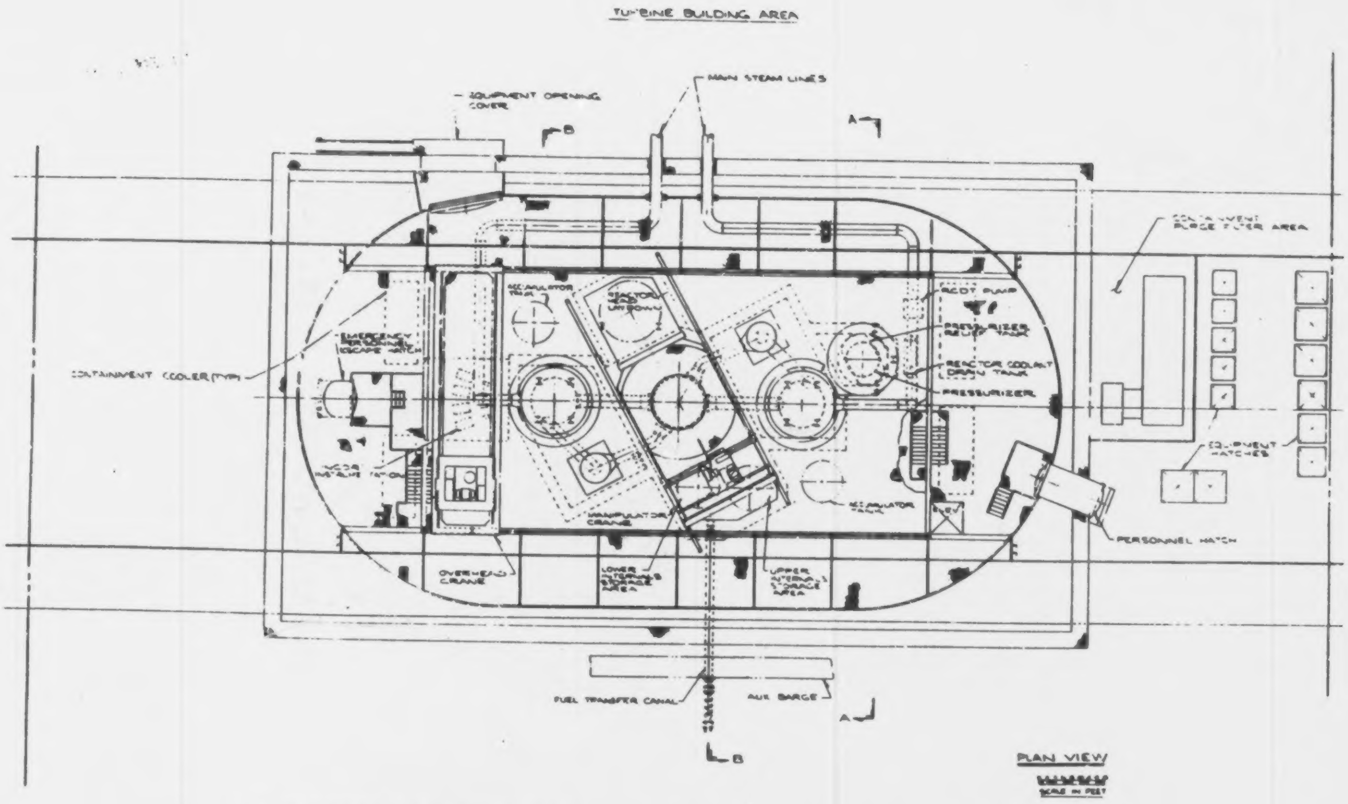
The NUPACK concept is a significant development that offers the potential for a cost effective application of nuclear power through an imaginative adaptation of modularization. The expected result will be a power plant design with predictable cost and schedule along with other benefits including improved quality and, in some instances, utilization of otherwise unuseable sites.

Further investigation is necessary to substantiate and quantify these benefits.


590 ft
187 ft
100 ft DIA

5620-1

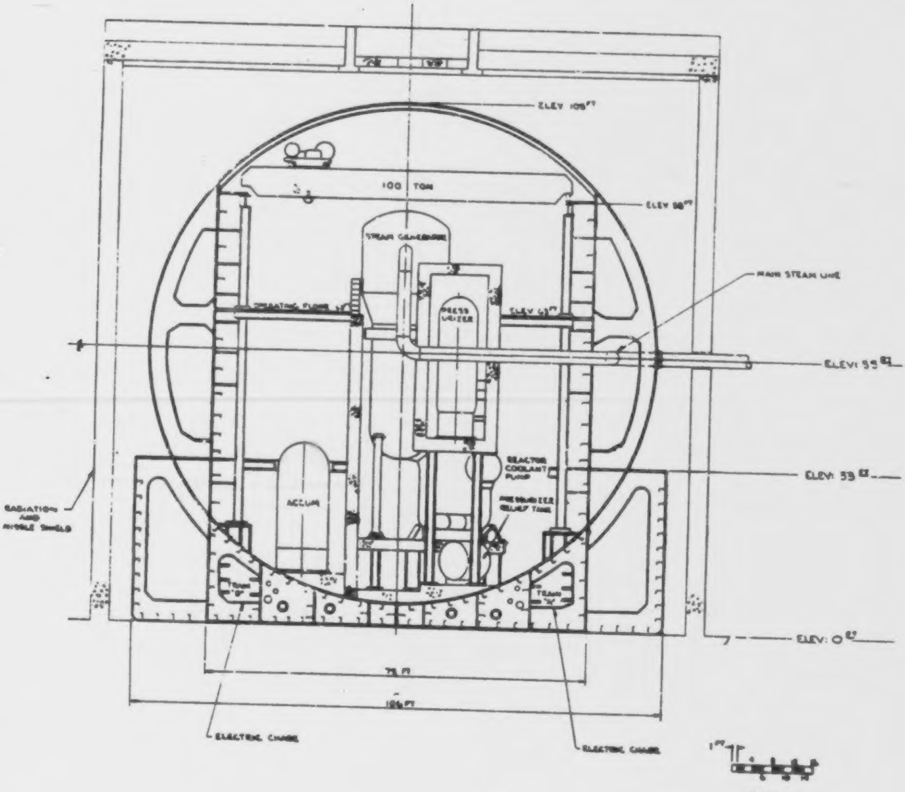
600 MWE NUPACK — LONGITUDINAL SEC
Fig. 1


TURBINE BUILDING AREA
EQUIPMENT OPENING COVER
MAIN STEAM LINES
CONTAINMENT PURGE FILTER AREA
ACCUMULATOR TANK
REACTOR HEAD LAYDOWN
RCDT PUMP
PRESSURIZER RELIEF TANK
REACTOR COOLANT DRAIN TANK
PRESSURIZER
EMERGENCY PERSONNEL ESCAPE HATCH
CONTAINMENT COOLER (TYP)
INCORE INSTRUMENTATION
MANIPULATOR CRANE
ACCUMULATOR TANK
ELEV
EQUIPMENT HATCHES
PERSONNEL HATCH
OVERHEAD CRANE
LOWER INTERNALS STORAGE AREA
UPPER INTERNALS STORAGE AREA
FUEL TRANSFER CANAL
AUX BARGE
A
A
B
B
PLAN VIEW
SCALE IN FEET

600 MWE NUPACK — CONTAINMENT PLAN VIEW
Fig. 2

5620-6
5650

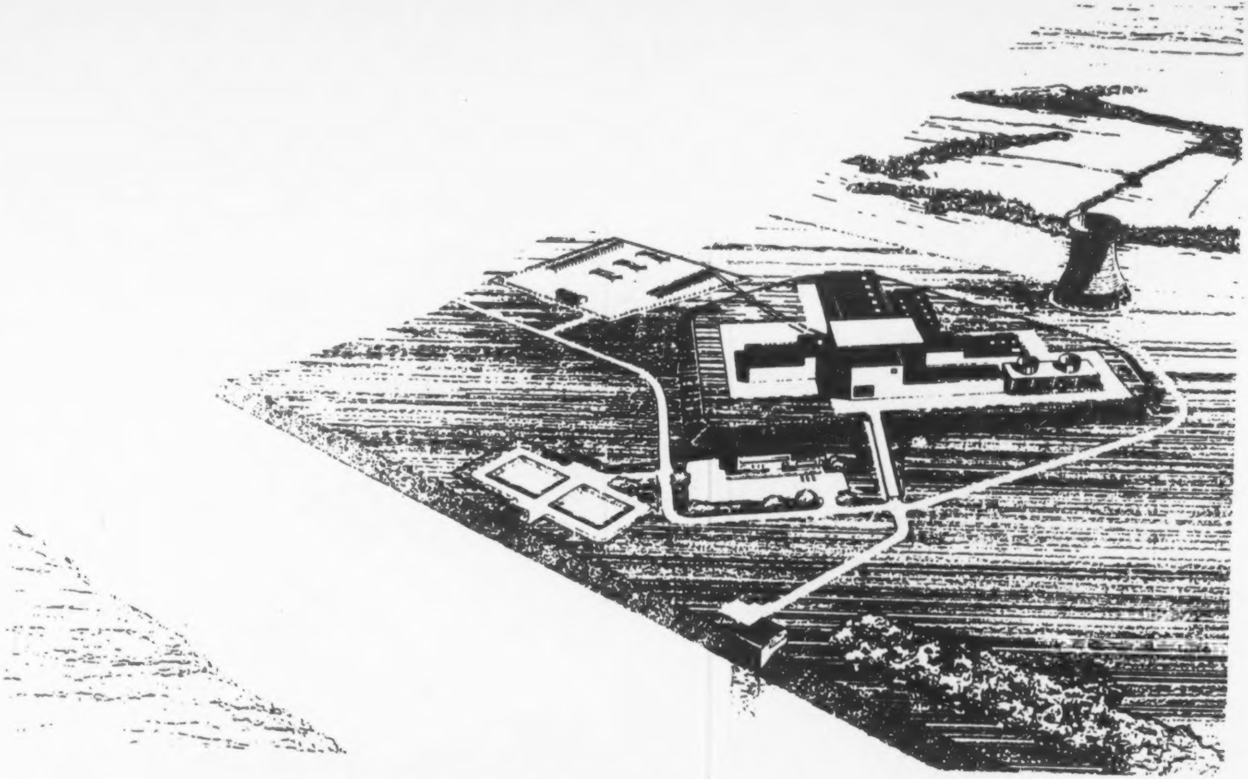
5620-6
5650


ELEV 105 FT
100 TON
ELEV 98 FT
STEAM GENERATOR
MAIN STEAM LINE
OPERATING FLOOR
PRESSURIZER
ELEV 63 FT
ELEV: 55 FT
REACTOR COOLANT PUMP
ELEV: 33 FT
ACCUM
PRESSURIZER RELIEF TANK
RADIATION AND MISSILE SHIELD
TANK "B"
TANK "A"
ELEV: 0 FT
75 FT
186 FT
ELECTRIC CHASE
ELECTRIC CHASE
SCALE

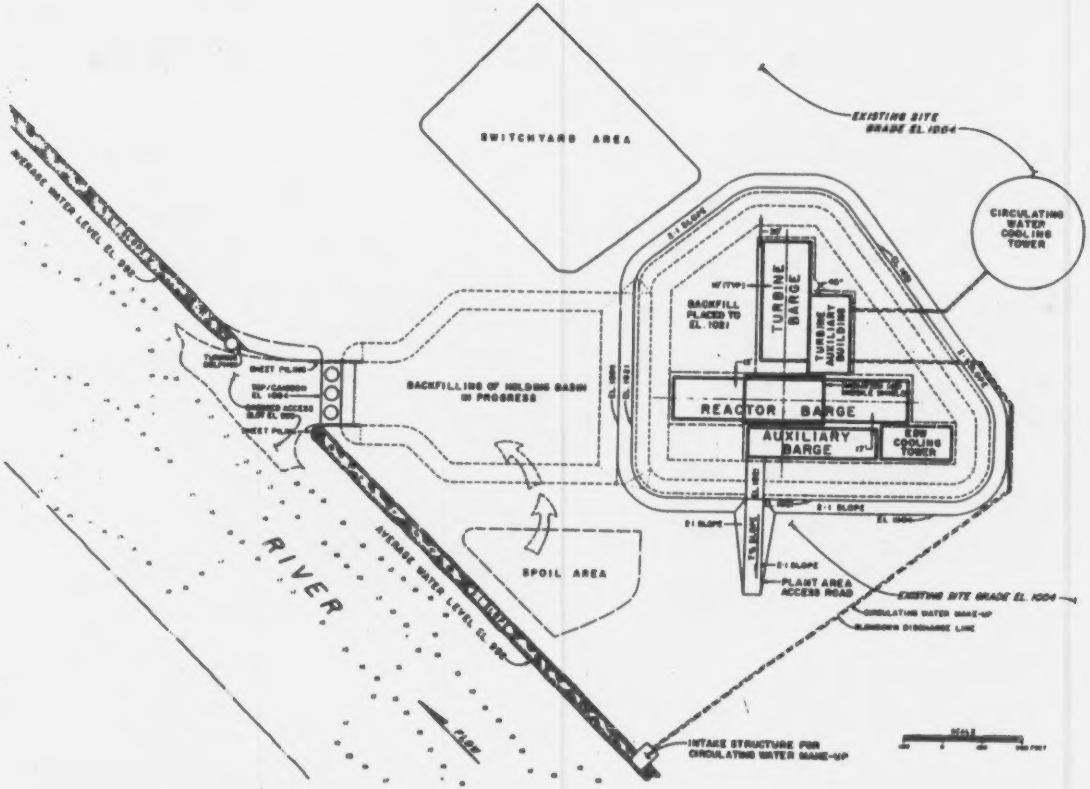
SECTION A-A

600 MWE NUPACK — SECTION
Fig. 3

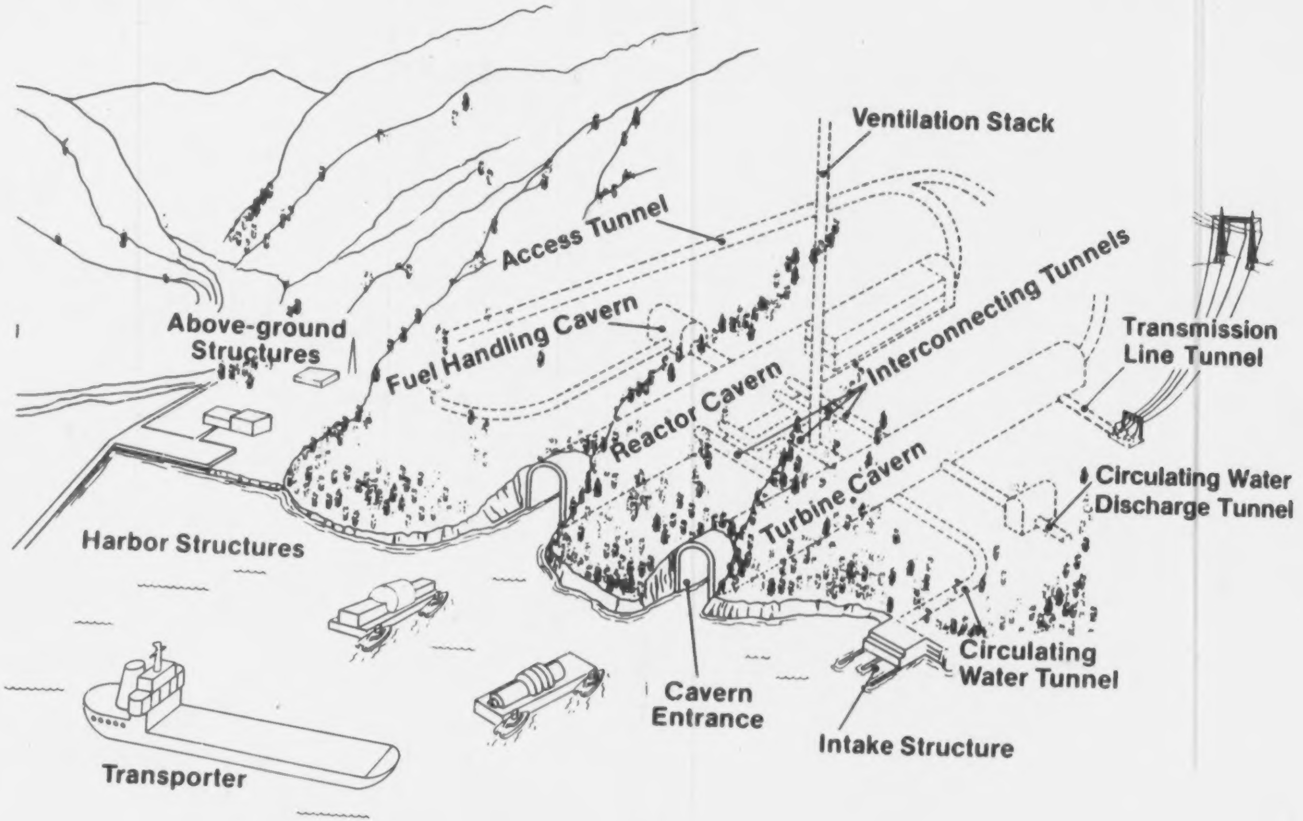
5650



NUPACK INSTALLATION ON RIVER SITE
Fig. 4

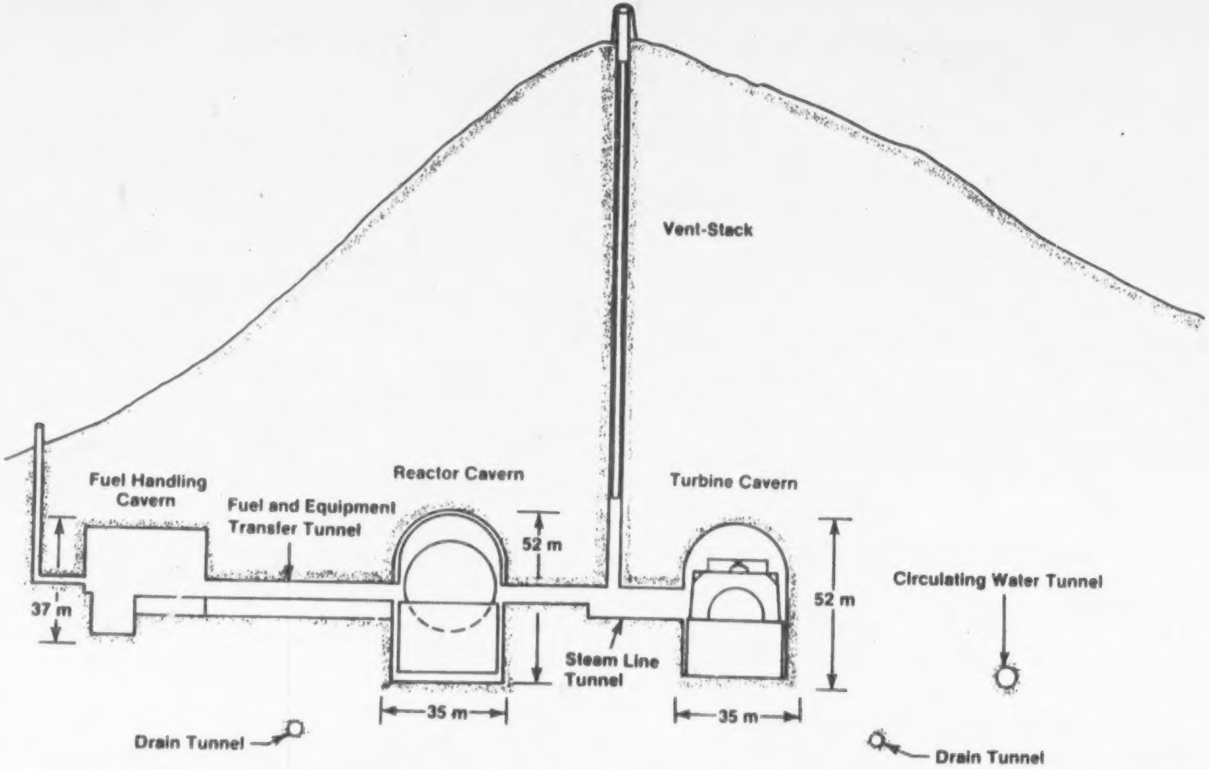

SWITCHYARD AREA
EXISTING SITE GRADE EL. 1004
CIRCULATING WATER COOLING TOWER
2:1 SLOPE
BACKFILL PLACED TO EL. 1021
TURBINE BARGE
TURBINE AUXILIARY BUILDING
REACTOR BARGE
AUXILIARY BARGE
ESW COOLING TOWER
EL. 1004
EL. 1021
2:1 SLOPE
PLANT AREA ACCESS ROAD
EXISTING SITE GRADE EL. 1004
CIRCULATING WATER MAKE-UP
BLOWDOWN DISCHARGE LINE
BACKFILLING OF HOLDING BASIN IN PROGRESS
SPOIL AREA
SHEET PILING
TOP/CAISSON EL. 1004
SHEET PILING
AVERAGE WATER LEVEL EL. 992
AVERAGE WATER LEVEL EL. 992
RIVER
FLOW
INTAKE STRUCTURE FOR CIRCULATING WATER MAKE-UP
SCALE

PLAN OF NUPACK INSTALLATION ON RIVER SITE
Fig. 5


Ventilation Stack
Access Tunnel
Above-ground Structures
Fuel Handling Cavern
Interconnecting Tunnels
Reactor Cavern
Transmission Line Tunnel
Turbine Cavern
Circulating Water Discharge Tunnel
Harbor Structures
Circulating Water Tunnel
Cavern Entrance
Intake Structure
Transporter

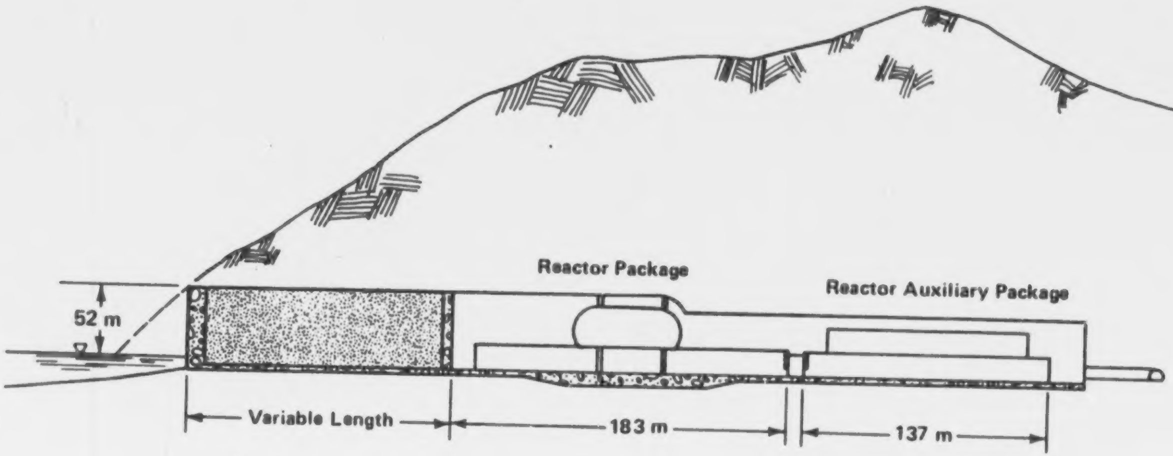
WHG. NUPACK — CAVERN INSTALLATION
Fig. 6

5620-3
5660


Vent-Stack
Fuel Handling Cavern
Fuel and Equipment Transfer Tunnel
Reactor Cavern
Turbine Cavern
52 m
52 m
37 m
35 m
35 m
Steam Line Tunnel
Circulating Water Tunnel
Drain Tunnel
Drain Tunnel

CROSS SECTION OF MAIN CAVERNS FOR WHG.
Fig. 7

5850


52 m
Reactor Package
Reactor Auxiliary Package
Variable Length
183 m
137 m

LONGITUDINAL SECTION OF REACTOR CAVERN
Fig. 8

5620-7
5650

M-84-17

Westinghouse Electric Corporation
Advanced Power Systems Divisions

Advanced Energy Systems Division
Madison Pennsylvania 15663-0158

January 30, 1984

Mr. Thomas A. Werner
Office of Nuclear Energy
Office of Convertor Reactor Deployment
U. S. Department of Energy - 19901
Germantown, Maryland 20874

Dear Mr. Werner:

Attached please find our recommendations on development work to support small liquid metal reactors (LMR). The attachment provides a listing of development items that are needed to support small LMR features and the priority for each new development item. Five of the top priority development items are described further in individual narratives. We can prepare similar narratives on additional priority items as necessary. Please let me know if we can be of further assistance in this matter.

Very truly yours,

J. R. Maxwell

J. R. Maxwell, Manager
Marketing

Attachments

REQUIRED DEVELOPMENT ITEMS FOR SMALL LMR'S

SMALL LMR PLANT FEATURES	SUPPORTING DEVELOPMENT	PROGRAM STATUS	NEW PROGRAM PRIORITIES	ESTIMATED COST OF NEW PROGRAMS (M$)
1) Integrated Fuel Processing	1) • SAF	In current plans	-	-
	• BRET	Phased out, recommend reinstated	3	Reinstate original amt.
	• FMEF	In current plans	-	-
	• Waste Disposal	In current plans	-	-
	• HFEF	In current plans*	1	1.0
	• Develop licensing criteria with NRC	New	2	0.5
2) Steel Building Structures	2) • Seismic Response & Damping	In current plans*	1	1.0
3) Inherently Safe Shutdown	3) • SASS Development	In current plans*	2	0.3
	• PRA for Single Shutdown System	New	2	0.2
4) Low Cost Fuel Assemblies	4) • Fuel Assy. Development & Test	In current plans*	3	1.0
5) Double Wall Tube Steam Generator without SWRPS	5) • Develop DWT-SG	In current plans	-	-
6) Shutdown Heat Removal System	6) • Natural Circulation Performance Methods and Testing	In current plans*	2	0.3
	• PRA for SHRS	New	2	0.2
7) Extremely Low Probability of HCDA	7) • Items 3 and 6	-	-	-
	• Natural Circulation Cooling of RCS	New	1	0.8
8) Mechanistic SSST	8) • Develop Data to Support Position	In current plans	-	-
9) Minimum ISI for RCS, and particular RV, GV & RV internals	9) • Prove leak before break and leak detection satisfies intent of boundary ISI	New	3	0.3
	• Define Design Guide to eliminate need for RV internals ISI	New	6	0.2
10) Generic License for Plant Integrated Structures	10) • Interface and develop criteria with NRC	New	2	2.0
	• Develop Universal General Design Criteria for Inherently Safe Reactors	New	3	3.0
11) Constant Length Hangers	11) • Proof Testing to Confirm Analysis	New	4	1.0
12) Water Pool Spent Fuel Storage	12) • Fuel Canister Design	New	5	0.2
13) Reactor Vessel/Deck Structure Bi-metallic weld	13) • Develop Long Life Weld	New	2	0.4
14) Two Stage Primary Sodium Pump	14) • Complete Large Pump Test	Deferred, recommend reinstating	4	Reinstate original amt.
15) Alternate Fuel Cycles	15) • Develop Carbide and Metal Fuels	In current plans	-	-
	• Develop Gel-Sphere Pac Oxide Fuel	New	5	0.7
16) Inherent Negative Thermal Reactivity Feedback	16) • Demonstrate Performance	In current plans*	2	0.5
17) Seismic Damping of Reactor Components	17) • Items 2 and 11	-	-	-
	• Damping of Structures in general	In current plans*	6	0.4
18) General Experience Base and Proof Testing of Previous Issues	18) • FFTF/HEDL	In current plans	-	-
	• EBRII	In current plans	-	-
	• ZPPR	In current plans	-	-
	• ETEC	In current plans	-	-
	• TREAT	In current plans	-	-
19) Plant Concept Demonstration	19) • Study modifications to Existing LMR Facilities - FFTF - EBRII	New	2	2.0-5.0
20) Small LMR Plant Design Concept	20) • Study Conceptual Designs	In current plans	-	-
21) CRBR Technology	21) • CRBR Termination Activities	In current plans	-	-
22) Power Conversion Technology	22) • Demonstrate Reliability of Plant Components	In current plans	-	-

* Identified in discussions of current plans but not obviously now being implemented for Small- Low Cost LMR Plants. Funding shown is to cover LCP Specific Development.

Steel Building Structures

Description: Develop and show to a conceptual design stage that steel building structures can be designed adequately for LMR's.

Justification: Regardless of any other improvement, the small LMR must be shown to be easily and inexpensively deployed. The Westinghouse designs for small, low cost plants incorporate extensive use of specialized building structures which are factory fabricated and installed at the plant site. This concept leads to a plant with greatly reduced costs as compared with other reactor concepts. However, steel building structures represent a departure from conventional nuclear island buildings in forms of seismic response. It is likely that steel buildings can be superior to concrete buildings because of larger damping coefficients. If this is proven to be true, then still greater cost reductions are possible. Also a seismically tuned building can lead to obtaining a generic license and can provide additional inherent safety.

Demonstrate Extremely Low Probability of HCDA

Description: Demonstrate by analysis and test that the small LMR has an extremely low probability of an HCDA. This effort would involve integrating work on inherently safe shutdown techniques, inherent shutdown heat removal techniques and others. This effort would be directed to show that HCDA and associated design features would not be required for the small LMR.

Justification: Elimination of HCDA from the design basis of the small LMR has many benefits. In current designs, the development of design criteria as well as mitigation features has contributed to the cost and complexity of LMR's. An investment is needed now to show that HCDA has an extremely low probability. This would eliminate the design and fabrication expense of HCDA mitigation features in the future. It is believed that with appropriate effort (application of inherent shutdown and heat removal techniques and adequate probalistic risk assessment) an extremely low probability for an HCDA will be shown. This should then relieve the regulatory requirement to design against a "what if" HCDA.

Licensing Criteria for Integrated Fuel Processing

Description: Develop with NRC a set of realistic licensing criteria for a fuel processing facility which is integral with an operating small LMR power plant.

Justification: The LMR is a unique reactor plant in-as-much as it has the ability to create its own fuel. Historically, this was envisioned to involve the deployment of several specialized facilities to produce and reprocess the fuel. However, one way to increase the competitive position of a small LMR is to have it integrated with its own fuel processing plant. To exercise this option requires obtaining a license for the fuel processing portion that will not jeopardize the entire plant. It is worthwhile, therefore, to develop the criteria necessary to license such a plant. The development must include the expertise of those experienced in fuel processing plant design and operation as well as NRC interaction. To develop realistic licensing criteria that has received NRC review and concurrence will minimize a potential impediment to plant development and deployment. Features necessary to satisfy licensing criteria can then be built in lieu of added on.

Generic Plant Integrated Structures License

Description: Perform design studies to determine a cost-effective generic plant integrated structures license. The license would be applicable to plants that have operating parameters within a defined envelope, and are located on sites having parameters within a defined envelope. This task will develop the integrated safety requirements for the barrier system, coordinate the preparation of design information required to support a generic plant integrated structures license, prepare licensing documentation and coordinate the licensing review with NRC.

Justification: The modular steel structure building approach not only leads to a low cost plant, but also allows the individual modules to have generic licenses. To a potential customer, already having a generic license greatly reduces the risk of cost and schedule overruns.

In the past, safety and licensing requirements have been identified for each new plant. This task will develop a set of requirements for the integrated modular systems that satisfies safety requirements. Current licensing requirements that may need to be modified will be identified. The designers would have flexibility to meet the integrated requirements using the most cost-effective barrier system.

Plant Concept Demonstration

Description: Study and recommend modifications to existing LMR facilities (FFTF and EBR-II) to provide the best demonstration by test and operation of small LMR design technologies.

Justification: A well developed concept or technology demonstration is worth much more than the equivalent amount of paper study justification. It is in DOE's best interest to determine now how to best apply its limited resources to a small LMR demonstration. One impediment to the deployment of a small LMR is convincing a potential customer that the design is based on proven plant operation and proven technology. The continued operation of FFTF and EBR II provide a significant amount of demonstration in this direction, however, the proof of safe and reliable operation will be enhanced if additional component operation is included. This demonstration could use an existing reactor to demonstrate or test anything from components to prototypic systems to a complete small LMR prototype. There are a number of opportunities for use of existing DOE facilities. The study should consider the cost effectiveness of demonstrating individual low cost components versus demonstration of complete systems with limited prior component developmental testing.

Westinghouse
Electric Corporation

Water Reactor
Divisions

Nuclear Commercial
Operations Division

Box 355
Pittsburgh Pennsylvania 152[illegible]

January 27, 1984

Mr. Thomas A. Werner
Office of Nuclear Energy
Office of Convertor Reactor Deployment
U.S. Department of Energy - 19901
Germantown, MD 20374

Dear Mr. Werner:

Please find attached program descriptions for the programs as discussed with Mr. Hollingsworth. Please let me know as to your needs for further information and funding estimates.

Very truly yours,

C. K. Paulson

C. K. Paulson, Manager
Plant & Integrated Systems Marketing

/sjq

Attachment

MODULARIZATION

This concept entails building modules of the nuclear power plant in factories.

The use of factory construction or assembly inherently offers greater potential for the necessary controls to allow schedules to be met while maintaining rigid and provable quality. Some movement in this direction was made previously, but it was relatively limited, possibly because the layouts and designs of plants did not lend themselves to any significant modularization in the very important areas of piping support and electrical cabling.

Very real limits on modularization occur due to limited ability to lift and transport large packages. Consequently, the ability to use modularization requires a departure from the conventional designs.

The full development and deployment of modularization requires a co-venture relationship between an NSSS supplier, possibly a high quality shipyard and a utility.

SMALL PLANTS

Economy of scale has become a tenet of faith in the nuclear industry. This faith may be ill founded however in that the final busbar cost of power over the life of a plant is impacted by a considerable number of factors which either do not follow the economy of scale rule or are indeterminable. Thus while it is probable that on a volumetric basis a large tank is always cheaper than a small one, it has not been proven that the same or better productivity can be achieved with a construction force of 8000 as compared to a force of 3000 or that a 1200 MWe unit can or will operate at the same capacity factor as a 600 MWe unit.

Additionally, the impact of market forces has yet to be fully felt. The diminishing role of heavy industry with its heavy power demand, reduced population and land growth rates, energy conservation, continued high interest rates and capital demands, potential impact from loss or damage of a unit are all subjective factors which suggest that traditional types of financial/cost analyses based largely on an economy of scale foundation may no longer be believable. Furthermore, the one remaining major argument for large units, joint ownership, may have foundered on the recent experiences of WPPS and Zummer.

In considering small units, however, it is still indisputable that with current system and plant designs there are major economy of scale penalties that will be difficult to overcome. Consequently, the economic soundness of small plant proposals requires the development of new system, equipment and plant designs that will require major expenditures and may ultimately depend on a government decision to retain the nuclear option.

Thus, a program to investigate constructability and schedule, operability, simplicity as opposed to economics of scale would be useful in guiding the nuclear industry as to appropriate power plant ratings.

QUALITY ASSURANCE IMPROVEMENTS

This is a plan for improving the quality in nuclear power plants in order to achieve the highest level of safety improved reliability and availability and concomitant reduced construction and operating costs. The plan consists of essentially two thrusts, a proactive effort and a reactive effort. The proactive program is made up of a number of separate and independent efforts which will have the following goals:

- promotion of the "standard plant" concept.
- advocate new regulatory legislation to promote "quality", e.g. authorize the NRC is to adopt a program similar to that utilized by the Federal Aeronautics Administration to enhance engineering and construction quality assurance in the aircraft industry. Under such program, the NRC would appoint highly qualified industry personnel as engineering and inspection representatives of the NRC to work within their respective organizations to ensure that work done conforms to NRC requirements.
- develop an improved integrated quality control plan for the plant construction phase.
    - develop an improved overall organization structure, which could be implemented during the plant design and construction phase, which would clearly define the responsibilities for achieving "quality".
    - propose a procedure for improved enforcement of the quality control plan, e.g. more and better audits and inspection.
- improve overall management committment to "quality".

o develop a program aimed at instilling on the design and construction organizations the dedication to provide a quality product.

The need for improvement in quality has been clearly demonstrated by the problems that have been, and currently are being, experienced in the construction and operation of nuclear power plants. Obviously much valuable insight can be gained by looking back. In the reactive phase of the quality assurance improvement program, therefore, efforts will be focused on identifying and categorizing the problems previously experienced and the development of plans for eliminating or controlling their reoccurence. These plans should also be effective in precluding the incidence of new and different problems.

It is proposed that the initial phase of the reactive program begins with the review of the available history and the identification of the significant problems. This effort would include problem identification, description and classification by cause, severity and frequency of occurence. This latter activity would aid in prioritizing the problem solving efforts. When classifying the cause of the problems attention would be directed towards workmanship, tools, processes, materials, etc.

The areas where change is required should become obvious once the above information gathering phase is completed. The subsequent efforts should then be one of essentially plugging-the-gaps. This will improve those activities which are dedicated to assuring that the design, materials and workmanship in the plant meet the applicable safety and regulatory requirements.

NUCLEAR PLANT STANDARDIZATION PROGRAM

The overall objective of this program is to outline actions to be taken by the nuclear industry and government in order to shorten nuclear plant schedules to be on par with fossil plants.

Utility Industry

Determine an action program at the utility level, to be undertaken before commitments for new construction are made. This program would address:

- Pre-approval siting.
- Utility manpower and project management needs construction and operation.
- Optimum contractor scope of supply, i.e. Turnkey vs. separate contracts for NSSS, Architect Engineer and Constructor.
- Level of design necessary for one step licensing.

Nuclear Industry

Develop action program with the NSSS vendors and Architect Engineers to optimize the design, licensing review and construction of nuclear plants. This program would address:

- Standardized Plant Designs.
- Optimize Scope split between NSSS vendors and Architect Engineers.
- Design simplification to optimize construction.
- Extent of design to be completed prior to construction.

Government Level

Develop action programs with local, state and federal government to streamline the licensing process. This program would address:

- Pre licensing of sites.
- Pre licensing of standard plants.
- Organizational structure and project management needed to minimize licensing reviews.

DESIGN AND CONSTRUCTION SIMPLIFICATIONS

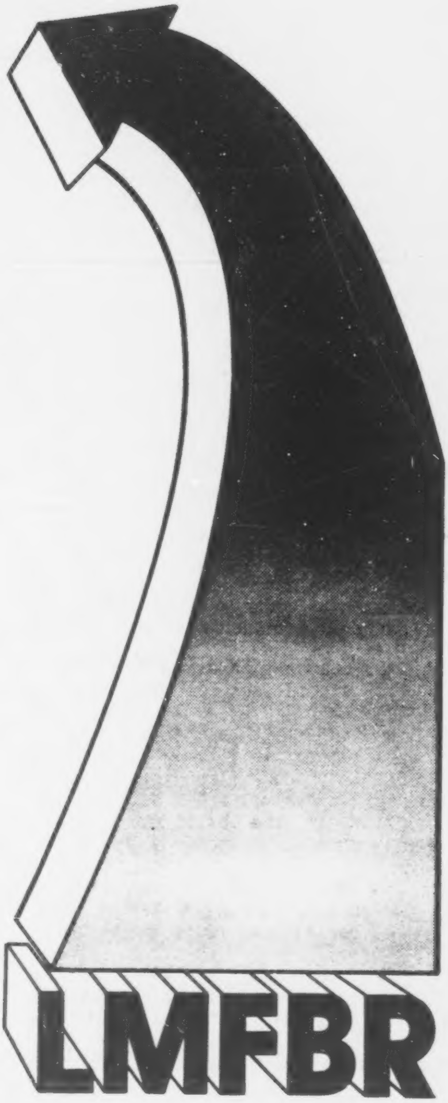
- Benefits of Design Simplifications are:
  - Reduction in project schedule.
  - Reduce design and construction costs of new plants.
  - Removal or reduction in complexity of designs results in reduced complexity of operations and maintenance, and lower plant operating costs.
  - Improved plant reliability and availability, improved capacity, and lower total power costs.
  - Backfitting simplified designs into existing plants will also improve availability and reduce power costs.

- Examples of Potential Design Simplifications are:
  - Relaxed pipe break criteria for high energy piping systems (RCS) in lieu of current NRC criteria. Relaxed criteria is based on using material test data and fracture mechanics evaluations to demonstrate that even if a large crack existed in a pipe the crack would not result in a pipe break, and that leakage through the crack would be detected.
  - Permit use of refueling cavity for emergency water storage and eliminate separate emergency water storage tank. Another variation (which would result in comparable benefits) adopts a single in-containment emergency water storage tank that would be the source of water for safety injection, containment spray, and refueling.
  - Eliminate provisions for adding sodium hydroxide to the containment spray system to remove elemental iodine assumed to be released from the core to containment during accidents. Post-TMI-2 studies suggest that very little elemental iodine will exist following an accident. In addition, it is recommended that the containment spray system itself be eliminated - pending

completion of evaluations to show that spray is not needed for post-accident containment cooling.

- Use the new ANS Decay Heat Curve in all accident analyses (LOCA and non-LOCA) which is already approved for use in Japan, and which will mainly result in more margin available for some accidents.
- Adopt a more realistic Operating Basis Earthquake (OBE). This will have the effect of reducing seismic requirements by reducing the level of the OBE to an Operating Shutdown Earthquake (OSE). Currently the OBE (not SSE) may control seismic design (particularly in the case of piping systems). By defining an OSE much less than an SSE, the SSE would always control the seismic design. Use of an OSE is lieu of an OBE may also have potential benefits relative to seismic qualification testing of I&C equipment.
- Replace single failure criteria and conservative design transients, presently in use, with a Probabilistic Risk Assessment approach. The PRA approach will (1) prioritize safety concerns and put them in proper perspective and (2) provide a rational basis for evaluating the impact of a specific safety concern on both components and systems, and the total plant.

THE U.S. LMFBR PROGRAM: FUTURE FOCUS AND DIRECTION



NOVEMBER 22, 1983

DR. W. H. ARNOLD
GENERAL MANAGER
WESTINGHOUSE
ADVANCED ENERGY SYSTEMS DIVISION

"We can cancel Clinch River...and at the same time continue our base breeder reactor program...The breeder reactor option will still be there if we choose to exercise it in the future."

Senator Gordon Humphrey

October 26, 1983

Since 1972, the Clinch River Breeder Reactor Plant (CRBRP) Project has been the principal focus of the U.S. LMFBR program. The Project has provided important direction for the LMFBR base technology program; it has been the spearhead for valuable and productive NRC safety review; it has served as an effective instrument for getting utility user input to the design, construction and operation of an LMFBR power plant; it has been an indispensable mechanism for establishing an industrial infrastructure for the engineering, manufacturing, and testing of LMFBR systems and components; and it has become the primary source of the nation's highly skilled and experienced LMFBR design engineers. The CRBRP Project succeeded in fulfilling its technical as well as its programmatic objectives until its recent termination.

The LMFBR program objective of providing a viable energy option for the U.S. in the next century remains unchanged. However, with the termination of the CRBRP Project, we must formulate new elements to accomplish those objectives of the program that hinged on construction and operation of CRBRP. To that end, we have identified the following elements as essential to maintaining a viable LMFBR program without CRBRP:

- Maintain the present strong LMFBR Base Technology Program by emphasizing key elements of current programs.
- Enhance international cooperation by participating in exchanges with foreign technology and demonstration plant programs.
- Confirm state-of-the-art components as well as operability and maintainability in a power plant environment by modifying FFTF to produce electricity.
- Verify the ability to license an LMFBR in the United States by completing the Construction Permit for CRBRP.
- Preserve the ability to accomplish future plant designs by documenting CRBRP key data and experience and completing certain key tests.

These objectives provide a new focus to maintain a mission-oriented breeder program that will provide a viable energy option and will continue to advance the technology to the point where the private sector can make market decisions regarding future commercial development. Each of these objectives of the restructured program has certain vital underlying elements.

Continue the Present Strong LMFBR Base Technology Program

The vital elements of the current Base Technology Program include:

- FFTF/EBR-II Operation and Testing
- SAF/BRET Development, Construction and Operation
- Fuels and Materials Development and Testing
- Plant Component Development
- Safety Technology Studies
- Low-Cost Plant Design

Each of these elements has an important role in the restructured breeder program. The Fast Flux Test Facility (FFTF) and Experimental Breeder Reactor-II (EBR-II) are used to evaluate overall performance of reactor designs through an integrated test of systems and components in an operating environment. Realistic tests of advanced components, such as the double wall tube steam generator design, can be tested in EBR-II. The FFTF tests breeder fuels and materials to evaluate performance under prototypic reactor operating conditions and provides valuable operating and maintenance experience with a sizeable fast reactor.

Essential breeder fuel fabrication development to minimize cost and personnel exposure are being carried out under the Secure Automated Fabrication (SAF) Line Program. Fuel reprocessing options are being evaluated at the Breeder Reprocessing Test (BRET) Facility to permit effective closure of the breeder fuel cycle.

Plant component development programs must continue in order to validate advances in the technology by demonstrating fabrication and operation of advanced designs. Inherent safety is being enhanced through safety technology studies. These major development programs provide focus for the component technology. In turn, our excellent technology used in component design and manufacture, testing methods, and safety studies provides an avenue for exchange with demonstration plant programs in other countries.

Design programs aimed at providing low-cost plant designs preserve the option for expeditious development of a state-of-the-art demonstration plant when called upon by our need for energy in the future. These programs incorporate advances in technology and changes in utility requirements. The information derived from these programs can be used to set priorities for the limited resources of the Base Technology Program.

In summary, the restructured Base Technology Program must preserve the strengths of the current program as well as undertake new initiatives that accomplish some of the objectives that once hinged on the construction and operation of CRBRP.

Enhance International Cooperation

Overseas programs have strong demonstration plant projects while our program has excellent technology in component development. These complementary strengths recommend exchanges of mutual benefit which include:

- A balanced engineering and hardware program with Japan (MONJU); and
- A licensability program with France (Super Phenix 2).

All major industrialized countries of the world have active LMFBR programs in place. The Japanese have recently obtained a construction permit for their MONJU loop-type demonstration plant, and construction will begin soon. Site work is well underway. However, only the preliminary designs of systems and components have been completed. In Japan, materials are not even ordered prior to receipt of the construction permit. Contracts have just been placed for detailed design of components. The status of the MONJU plant still permits accommodation of innovations, features, and components. In contrast, the CRBRP stands near the completion of component design and testing. More than 75 percent of the equipment was on order with $380M worth of equipment in storage or testing.

The excellent U.S. technology in components and testing together with our manufacturing experience and available hardware are valuable equity for exchange with Japan. The benefits of this type of cooperative arrangement with the U.S. breeder program would be substantial. Demonstration in MONJU would confirm technology and designs and would also involve additional confirmatory testing in U.S. facilities. It would enable us to acquire construction, operation, and maintenance experience data as well as advanced Japanese technology.

The French breeder plant program, particularly the Super Phenix 2, offers another important opportunity for international cooperation of mutual benefit. If it is determined that the Super Phenix 2 is licensable by the NRC and that it offers operational characteristics satisfactory to U.S. utilities at reasonable cost, this knowledge could be factored into breeder reactor options for the United States.

Previous evaluations of the pool-type Phenix plant have been inconclusive. Some critics conclude that the plant should be available as a fallback while others have asserted that an NRC license could not be obtained. Any conclusive evaluation must include the direct participation of the NRC. An evaluation of Super Phenix 2 with NRC review is recommended as a high priority addition to the U.S. breeder reactor program.

In addition to establishing the viability of the Super Phenix 2 as an option for the United States, the joint DOE/NRC evaluation would be of substantial benefit to the French. Because of the benefit to France, partial funding for this evaluation or equitable technology items should be provided by them.

In summary, enhanced international cooperation is recommended as an important element in the restructured Base Technology Program to preserve the breeder reactor option for the United States. A balanced exchange of U.S. engineering and hardware for participation in the MONJU demonstration plant would be mutually beneficial to the United States and Japan. An evaluation of the Super Phenix 2, which establishes licensability by the NRC, would be of mutual benefit to the United States and France. Through these programs, the United States will derive value from the investments already made in CRBRP and determine the viability of both loop and pool alternative breeder reactor options.

Confirm Components in Electrical Power Generation at FFTF

Confirmation of steam generator design, manufacture, installation, operation, inspection, and maintenance in a power plant environment is considered to be an essential element in a restructured Base Technology Program. This can be accomplished by adding CRBRP state-of-the-art components to the FFTF in a manner that will:

- Maintain the FFTF as a reactor test facility;
- Create a valuable component test;
- Demonstrate a breeder core; and
- Offset costs by providing electricity for Hanford.

The use of CRBRP components offers an opportunity for DOE to expand the scope and mission of FFTF to obtain a component test bed that pays for itself in five to seven years by producing electricity for Hanford. This will accomplish the original CRBRP mission of evaluating the overall performance of key components in an integrated test of reactor subsystems and components as well as plant operability and maintainability. The concept of greatest value would require all the steam system components, the turbine generator, and the electrical transmission equipment. The value of FFTF as a reactor test bed would be maintained. The component test facility would enable accelerated life testing of future components from the Base Technology Program.

The demonstration of heterogeneous core performance in the FFTF is also an element of component testing. Fabricating an advanced breeder core for operation in the FFTF will confirm high burnup fuel, long-life materials, and inherently safe features and will validate many design considerations as well as breed fuel at a rate comparable to foreign breeder reactors.

In summary, renewed emphasis on work at the FFTF, with some restructuring of the direction of ongoing studies, could fulfill several functions. It could provide a power source for future needs; establish essential information on breeder technology; and assist FFTF in remaining a source for the testing of engineering concepts in the breeder program. It is also possible to realize substantial cost savings if CRBR components are used.

Verify the Licensability of a U.S. LMFBR

From the point of view of industry and utilities, licensability is a most important LMFBR issue. Completing the Construction Permit (CP) for the CRBRP is essential to demonstrating the viability of the breeder reactor option to the United States and other nations. All the requirements for the CRBRP CP have been met. No additional engineering costs will be incurred. Only an inter-agency transfer of a $2,000,000 fee is required. The CP is the verifiable certificate of accomplishment that is necessary to industrial participants and utilities. Progress already made in the CRBRP licensing program must not be lost in the restructured LMFBR Base Technology Program. The Super Phenix study proposed above would also contribute to further understanding in this area as well as keep key NRC personnel active in the LMFBR area.

Preserve the Design Data

The future design and licensing accomplishments of the restructured Base Technology Program will rest upon the accomplishments of the CRBRP Project. Actions to preserve these accomplishments by preserving the design data include:

- Documentation of engineering decisions;
- Documentation of lessons learned;
- Documentation of manufacturing experience; and
- Complete certain key component tests.

These actions are necessary to continue the present strong Base Technology Program as well as to undertake the new initiatives outlined above.

The documentation provides effective orderly termination of the CRBRP system design and licensing activities in a retrievable form. This includes completion of selected areas of design and closeout of licensing after the CP with development of lessons learned and preparation of final reports. Design data and experience will be preserved in reports, design handbooks, drawings, computer codes, and important vendor documentation. Documentation of the specifics of the interactions with the NRC that were necessary to obtain the CP, including specific data and committed development programs, will have particular importance to utilities and future plant design studies.

LMFBR: A New Direction

In summary, the restructured Base Technology Program must preserve the strengths of the current program as well as undertake new initiatives that accomplish some of the objectives that once hinged on the construction and operation of CRBRP. This will continue a mission-oriented breeder program and maintain the U.S. position as technological leader in this essential energy technology.

Ms. LLOYD. Thank you very much.
Mr. Williams.

STATEMENT OF ROBERT O. WILLIAMS, JR., PRESIDENT, ENERGY SYSTEMS GROUP, ROCKWELL INTERNATIONAL

Mr. WILLIAMS. Thank you, Madam Chairman.

I am Robert Williams, president of the energy systems group of Rockwell International Corporation.

We have been deeply in the design, development, and operation of advanced nuclear reactors for commercial power and space applications for more than 30 years, and it is from this perspective that I wish to address the subject of advanced reactor power systems. Specifically, I will discuss first the results of our studies on advanced, low cost, inherently safe liquid metal cooled reactors for commercial power generation; and secondly, some examples of the application of existing technology to two defense terrestrial reactor applications of current interest; and third, our views on space nuclear power systems, an area where our experience in the space nuclear auxilliary power program is unique in the free world, and our company's extensive role in the U.S. space program provides additional valuable insight.

Some of our recent LMFBR design and development efforts, there have been some sharpening focus, along with all of the other organizations on it, advancing low plant cost and capitalizing on the inherent safety characteristics of the sodium systems. These design efforts have addressed plant sizes ranging from the very large units, which we have been studying over most recent years, the 1350 MW size which might be projected for longer-term needs, down to the smaller sizes such as 300 MWe which might be more appropriate for the near-term markets.

A recent joint design effort by Rockwell International, Argonne National Laboratory, and Combustion Engineering has produced particularly promising results in addressing plant sizes in this entire range.

We have developed designs for pool-type plants which incorporate passive safety features providing excellent assurance for the protection of personnel and plant investment. Detailed comparisons of these designs with alternate LMFBR designs and of coal and LWR plants show our designs require substantially less construction quantities and have excellent potential for being very competitive and proliferation resistant.

The liquid metal fast reactor development program, in our view, should give priority to establishing a credible basis for low-cost, economically competitive plants; second, developing a defensible licensing position, building on the inherent safety advantages; third, providing financial risk levels commensurate with private sector funding; and, fourth, examining potential improvements in fuel cycle reprocessing technology, but, we think, deferring reprocessing demonstration plant construction until that market need develops.

To achieve these results, the program should have as a focal point the development of competitive, innovative, low-cost designs offering enhanced safety. These designs should be the basis for a constructive dialog, including utility participation, with the Nuclear Regulatory Commission. A strong test program should be conducted in support of these design studies, aimed at substantiating component and system characteristics which provide the lower cost and enhanced safety.

With the technology already available, and a strong system component testing program, user and investor confidence can be earned. This approach will also provide a sound basis for beneficial international collaboration on fast reactor development and demonstration.

This same basic technology is also applicable to defense and space applications where high performance and safe reliable operation is required. For example, compact reactor systems would be ideal for meeting the north warning system power requirements. This 10- to 20-kilowatt electric application requires systems that are low in capital cost, reliable, inherently safe, and transportable. Capital and life cycle costs must be kept low in order to compete with the overall diesel generation life cycle cost. Unattended operation for up to 18 months demands highly reliable, essentially static systems.

The only reactor concept that we know which has operated with no operator intervention for a period approaching 18 months is the SNAP-10A Flight System 3. This ground demonstration of the SNAP-10A flight reactor operated at about 1,000° F outlet for 10,000 hours. Its heat was converted to electricity by a static thermalelectric converter radiator.

It would appear logical to use this developed SNAP technology for this remote basing application. The reactor would drive a thermalelectric converter, cooled by the heatpipe technology developed at Las Alamos National Laboratory. It is the only concept that has been taken through that full factory to site sequence that would be required for remote basing application.

The development required to apply this technology to this mission are the economic validation, non-nuclear test of the thermal electric converter/heatpipe configuration, and non-nuclear heat system tests of natural cooling capability inherent in the system. The facilities needed for such tests already exist at the Energy Technology Engineering Center. Since economics are primarily driven, in this case, by fuel fabrication and thermalelectric converter/heatpipe costs, optimization of fabrication processes and facilities tasks industrial concerns are best qualified to do is required.

In our opinion, this approach is the only concept that could meet a near-term deployment schedule. The SNAP reactor development cycle took 10 years from initial concepts in the 1950's to launch deployment in the 1960's.

For the defense terrestrial reactor for military base applications, a similar approach utilizing existing fast reactor technology coupled to a commercially available Brayton cycle could provide a compact, inherently safe system, keeping all items well within their proven performance envelopes. The development needs for this approach are similar to that for the remote base application.

For space nuclear power systems, ongoing research appears to be concentrated on advanced high-temperature concepts that, to us, imply high technical risk and a long, expensive development program. It seems to us that a liquid metal reactor driving a dynamic

Brayton or Sterling conversion system represents a logical system to develop to assure a near-term availability of the nuclear option for space power.

An aerospace safety program similar to the successful one performed for the SNAP program in the 1960's should be initiated as an integral part of the overall space nuclear power development program.

In summary, our recommendations for the continued development and improvement of nuclear power systems to meet future energy requirements are:

Continue the research and development of LMFBR's in concert with international developments, emphasizing cost reduction and inherent safety factors in order to preserve the option for future deployment as a logical successor to light water reactors;

Utilize existing technology made available from previous investments in both the LMFBR and the SNAP programs to the maximum extent possible in order to meet near-term requirements for special defense terrestrial and space power applications with acceptable total program costs;

And third, utilize the private nuclear industrial sector more, early in the development cycle to insure that practical cost effective solutions are pursued as well as the longer-range, higher technology and higher risk approaches.

Thank you for this opportunity to testify, and I hope my comments have been helpful. I will be happy to answer any questions you may have.

[The prepared statement of Mr. Williams follows:]

PREPARED STATEMENT OF ROBERT O. WILLIAMS, JR., PRESIDENT, ENERGY SYSTEMS GROUP, ROCKWELL INTERNATIONAL CORP.

INTRODUCTION

I am Robert Williams, president of the Energy Systems Group, Rockwell International Corporation. We have been deeply involved in the design, development, and operation of advanced nuclear reactors for commercial power and space applications for more than 30 years and welcome this opportunity to present our views on this subject.

Although the more than 11,000 employees of the Energy Systems Group have a wide range of skills in the nuclear business, we believe that our principal expertise which is most relevant to this subject--advanced reactor systems--is in the design and operation of liquid metal-cooled reactors.

Our experience in this field includes the pioneering research, development, design, construction, and operation of eight liquid metal-cooled reactors for terrestrial and space applications in the 50's and 60's; a major role in the U.S. Liquid Metal Fast Breeder Reactor Program since its inception; and the design, construction, and operation for the past 18 years of the world's largest facility for testing liquid metal components--the DOE's Energy Technology Engineering Center. The nation's past investments in liquid metal-cooled reactors provide a heritage of technology which is applicable to many if not all of the requirements currently foreseen for commercial, defense-terrestrial, and space nuclear power plants. It is from this perspective that I wish to address the subject of advanced reactor power systems.

Specifically, I will discuss (1) the results of our studies on the potential of advanced, low-cost, "inherently safe," liquid metal-cooled reactors (LMRs) for commercial power generation, (2) some examples of the application of existing technology to two defense terrestrial reactor applications of current interest, and (3) our views on space nuclear power systems--an arena where our experience in the space nuclear auxiliary power program is unique in the free world and our company's extensive role in the U.S. space program provides additional valuable insight.

We continue to believe that the LMFBR is the most promising, most practical energy source which can be commercially developed during the lives of most of us here today.

The great value of sodium-cooled fast reactors is recognized by most industrial nations of the world, as evidenced by the strong development programs overseas. Sixteen liquid metal fast reactors and at least eight other sodium-cooled reactors have operated in six countries. Operation of these plants has proven to be comparatively simple, and the cumulative radiation exposures of plant operating personnel have been very substantially below levels associated with light water reactors. The exceptional inherent safety characteristics of LMFBRs have been well demonstrated in various reactor experiments. In one particular test with the Rapsodie reactor in France, conditions of loss of flow without reactor scram were deliberately imposed and the self-regulating characteristics of the reactor safely reduced power to a stable equilibrium level with passive cooling. No action by the operator was required. A TMI-2-type accident would not be possible in a properly designed liquid metal-cooled fast reactor.

We are fortunate to have had a strong base technology program in the U.S. for years, and this subcommittee has had an important role in making this possible. In the design and development effort in recent times, there has been a sharpening focus on achieving low plant costs and capitalizing on the inherent safety characteristics of sodium systems. These design efforts have addressed plant sizes ranging from large units (e.g., 1350 MWe) projected for longer term needs down to smaller sizes (e.g., 300 MWe) which may be more appropriate for near-term markets. The cost and quality advantages of modular building blocks of the 100-MWe size have also been studied. A recent joint design effort by Rockwell International, Argonne National Laboratory, and Combustion Engineering has produced particularly promising results in addressing plant sizes in this entire range. We have developed designs for pool-type plants which can accommodate both oxide and metal fuel approaches. The designs incorporate passive safety features which provide excellent assurance of the protection of personnel and plant investment. We also are reexamining the potential advantages of integrating reprocessing/refabrication facilities with the power plant, the original EBR-II concept. We have conducted detailed comparisons of these designs with those of alternate LMFBR designs and of coal and LWR plants. The results show our designs require substantially less construction quantities and have excellent potential for being very competitive and proliferation-resistant.

Where should we go from here? The slowdown in the growth rate of the nation's electrical generating capacity provides an opportunity which should be fully exploited. The program should be structured to move ahead with those steps which will have liquid metal fast reactors ready for the market when needed. To meet this challenge, the liquid metal fast reactor development program should give priority to (1) establishing a credible basis for offering low-cost, economically competitive plants; (2) developing a defensible licensing position, building on inherent safety advantages; (3) providing financial risk levels commensurate with obtaining private sector funding of a demonstration power plant; and (4) examining potential improvements in fuel-cycle reprocessing technology for oxide, metal, and carbide fuels but deferring reprocessing demonstration plant construction until a market need develops. To achieve these results, the program should have as a focal point the development of competitive, innovative, low-cost designs offering enhanced safety. These designs should be the basis for a constructive dialog (including utility participation) with the Nuclear Regulatory Commission, the purpose of which would be to obtain feedback and an appropriate indication of NRC position regarding the licensability of future liquid metal-cooled fast reactors.

A strong test program should be conducted in support of these designs aimed at substantiating component designs and system characteristics which provide lower cost and enhanced safety. Specific examples from our own studies include the performance and endurance testing of a shrouded inducer pump (developed as a spinoff of aerospace technology) which provides significant cost savings compared with other pump types under development. Another example would be the testing of an enhanced hockeystick steam generator, a significant cost-saving advancement over the CRBR prototype hockeystick steam generator which we designed and fabricated and successfully tested at the Energy Technology Engineering Center. With the technology already available and a strong system/component testing program of the type indicated above, user and investor confidence can be earned which will facilitate the introduction of liquid metal-cooled fast reactors into the market. The approach described above will also provide a sound basis for beneficial international collaboration on fast reactor development and demonstration.

The liquid metal fast reactor is a natural successor to light water reactors and is needed to sustain the nuclear option for commercial electrical supply. This same basic technology is also applicable to defense and space applications where high performance and safe, reliable operation is required. For example, we believe that compact reactor systems would be ideal for meeting the North Warning System power requirements. This 10- to 20-kWe power level basing application requires systems that are low in capital cost, reliable, inherently safe, and transportable. Capital and life cycle costs must be kept low in order to compete with diesel generation. Unattended operation for up to 18 months demands highly reliable, essentially static systems. The requirement for systems with inherent safety follows from the requirement for unattended operation and transportability.

The only reactor concept that we know of that operated remotely, with no operator intervention for a period approaching 18 months, was the SNAP 10A FS-3. This ground demonstration of the SNAP 10A flight reactor operated at about 1000°F outlet for 10,000 hours in a vacuum chamber. Its heat was converted to electricity by a static thermoelectric converter-radiator. There was no operator intervention except for remote monitoring of diagnostic instrumentation. The operation was flawless and post-test examinations verified that there was no damage to fuel, drives, or the electric conversion system. Indeed, the fuel looked as it had when installed new. Higher power and higher temperature (up to 1300°F outlet) SNAP systems operated up to 1-MW thermal for 5000-hour periods of uninterrupted, steady power.

The nearest term, new and innovative approach to the remote basing application, therefore, would be to apply this developed SNAP technology, at the same operationally proven temperature levels. Such a concept would drive a thermoelectric converter cooled by the heat pipe technology developed at Los Alamos National Laboratory. The fuel, control system, heat transfer system, and conversion system are proven and developed. The reactor power level (approximately 200 kWt) and temperature (1000°F outlet) are well within proven test regimes. Indeed, the factory-to-site safety analysis has been done for SNAP reactors, covering a wide range of accidents including transportation, water immersion, fire, and launch abort. It is the only concept that has been taken through the sequence that would be required for a remote basing application.

The development efforts required to apply this technology to this mission are: economic validation, nonnuclear tests of the thermoelectric converter/heat pipe configuration, and nonnuclear heat tests of natural cooling capability inherent in the system. It should be noted that the facilities needed for such tests already exist at the Energy Technology Engineering Center. Economics are primarily driven by fuel fabrication and TE/converter/heat pipe costs. Reductions in cost are achievable through optimization of fabrication processes and facilities, tasks that industrial concerns are best qualified to do. The factory-to-operation safety analysis should also be performed for the specific application making direct use of already existing SNAP documentation. These developmental activities should firm up capital and operating costs for comparison with alternative energy sources and provide an input to meet safety assurance requirements.

We must point out that, in our opinion, this approach is the only concept that could meet a near-term deployment schedule. The SNAP reactor development cycle took 10 years from initial concepts in the 50's to launch deployment in the 60's. New and innovative designs which lack similar specific test and operation data at appropriate operating conditions, as we did in the 50's, could be expected to take at least 10 years and a significant investment to develop and deploy in today's environment. Thus, the costly development of an entirely new concept or technology for this application appears to be neither required nor justified, considering the national concern with reducing the federal deficit. Instead, I believe we should capitalize on the hundreds of millions of dollars invested in the space nuclear power program two decades ago and determine the cost-effectiveness of utilizing this available, state-of-the-art technology to meet this current requirement.

For the defense terrestrial reactor, which must provide secure electric power for military bases, the emphasis is on cost, inherent safety, low operator requirements, transportability, and maintainability.

Again, cost is the fundamental driver, and cost relates to system size and state of development. Many approaches have been suggested, but it seems to us that the smallest, simplest, and safest new and innovative approach is, again, to use demonstrated components. We would use oxide fuel from the LMFBR programs which has been throughly demonstrated over the years, liquid metal-cooling technology, reflector control from SNAP technology, electromagnetic primary coolant pumps from CRBRP-developed technology, and private industry-developed Brayton gas turbine generators. A compact, inherently safe system can be provided with this approach keeping all items well within their proven performance envelopes.

The development needs for this approach are similar to that for the remote base application: nonnunclear tests of the configuration of the power conversion, natural circulation capability in the reactor, interaction with NRC to meet the licensability goal of the concept, and packaging studies to meet capital cost goals and transportability requirements. These studies are also driven by the marketplace and should be performed by industry to establish credible costs.

For space nuclear power systems, ongoing research appears to be concentrated on advanced, high-temperature concepts that to us imply high-technical risk and long, expensive development programs. It seems to us that an approach using a liquid metal reactor operating at LMFBR temperatures and lower power densities, driving a dynamic (Brayton or Stirling) conversion system with conventional or heat pipe-cooled radiators represents a logical system to develop to assure a near-term availability of the nuclear option for space power. An aerospace safety program similar to the successful one performed for the SNAP progam in the 60's, the methodology and general results of which still seem applicable, should be initiated as an integral part of the overall space nuclear power development program.

In summary, our recommendations for the continued development and improvement of nuclear power systems to meet future energy requirements are:

1. Continue the research and development of LMFBRs in concert with international developments, emphasizing cost reduction and inherent safety factors, in order to preserve the option for future deployment as a logical successor to light water reactors,

2. Utilize existing technology made available from previous investments in the LMFBR and SNAP programs to the maximum extent possible in order to meet near-term requirements for special defense-terrestrial and space power applications with acceptable, total program costs, and

3. Utilize the private nuclear industrial sector early in the developmental cycle to insure that practical, cost-effective solutions are pursued as well as the longer range, higher technology and higher risk approaches.

Thank you for this opportunity to testify. I hope my comments have been helpful, and I will be happy to answer any questions you may have at this time.

0050w/srs

Mrs. LLOYD. Thank you very much, Mr. Williams, for your fine statement.

Dr. Wolfe.

STATEMENT OF DR. BERTRAM WOLFE, VICE PRESIDENT AND GENENAL MANAGER, NUCLEAR FUELS AND SPECIAL PRODUCTS DIVISION, GENERAL ELECTRIC CO.

Dr. WOLFE. Thank you, Madam Chairman. I am delighted to have been invited here.

I have a full biography in the written testimony. Briefly, I received my Ph. D. from Cornell in 1954.

Dr. Arnold, I went to Princeton as an undergraduate.

I have been in the nuclear business for over 25 years, over two-thirds of which has been in advanced reactor development. I am presently a vice president of General Electric and general manager of its Nuclear Fuel and Special Projects Division. I am a professional engineer in California, a Fellow of the American Nuclear Society, and a member of the National Academy of Engineering, and have authored a number, several dozen papers on nuclear energy and energy.

Mrs. LLOYD. We certainly look forward to your testimony.

Dr. WOLFE. Thank you.

My company and I have been participants with the U.S. Government in the development of advanced reactors since the late fifties. As a commercial venture, General Electric was, of course, the leader in bringing the boiling water reactor, an advanced reactor of the 1950's, to commercial economic practicability.

In the late fifties we were the first commercial organization to start intense development of the mixed oxide fast breeder reactor, the leading concept, the breeder concept, in the world, and in the sixties convincingly demonstrated the safety basis of fast breeder reactors with the construction and operation of the highly successful SEFOR reactor.

We have both with our own resources and with Government help explored the characteristics of a myriad of proposed new reactor types. Recently, with DOE's support, we have been developing the modular breeder reactor concept and also the modular HTGR concept.

The modular breeder consists of a 100-megawatt reactor—100-megawatt electrical breeder reactor which can be factory built and shipped to the site assembled. Incidentally, it's limited to about a 15-foot diameter vessel and containment vessel, in order to allow for rail shipment. A number of such modules would be coupled together for large powerplant outputs.

Because of its small size and compact design, the modular breeder appears to have both safety and perhaps some large economic advantages, but in my view, its major advantage is that its development cost might be affordable, and we question whether the large reactor types, either breeders or gas-cooled reactors, can in today's environment be developed in the United States.

If I can depart from my written testimony, on the Clinch River breeder reactor, if that had gone forward as we tried to have it go forward and been wildly successful, the $3 billion or $4 billion spent on that would have been an invitation to spend another $5 billion on the 1,000-megawatt prototype, which if it had been successful would have been an invitation to spend another multibillions of dollars on the nearcommercial prototype. And in today's environment we're not sure that that kind of a development program converges.

We believe the modular reactor approach, where one builds a small module which then can be modified in place and tested and developed in place, and when it's done is the commercial reactor design—we believe that that has a possibility of being developed in today's environment at a cost which the Nation can afford; and we have the same view, I might add, with respect to that on the HTGR.

In addition, both of these concepts, because of their small size, allow for safety characteristics which seem to be somewhat improved over what one would get in any large size reactor; namely, we think in both cases one could take away the decay heat by just natural circulation to the atmosphere.

We believe that both of these concepts have promise for making major contributions in the future. However, as promising as these concepts are for the future, we're very concerned that perspective not be lost. These are concepts which cannot correct the problems of the present. And without such corrections, I believe no nuclear power program can be successful in the United States.

No reactor can tolerate bad welding in critical areas, poor electrical work, or other lapses in quality control. No reactor can afford the economic penalties of schedules artificially lengthened to match utility cash flow restraints rather than efficient construction.

It would be difficult in any major construction activity to successfully pass the baton through the complex relationships which frequently exist in nuclear projects between the utility owner, the architect-engineer, the reactor manufacturers, the consultants, other suppliers, and the regulatory inspectors.

And in my view, most serious of all, no reactor system or other power source can be successful or even survive in a regulatory system with ever-changing groundrules imposed with little predictability so that schedules can't be maintained, designs can't be frozen, and under conditions such that even when the plant is built, as in the case of Shoreham on Long Island, one is not sure whether it will be allowed to operate. Indeed, even after a plant has run the gauntlet and successfully reached operation, and in fact been praised by The New York Times—that is, the St. Lucie plant—one is not sure if an identical plant could repeat the performance.

These are the institutional impediments to a successful nuclear option. Arguments that our present problems can be corrected by new reactor concepts misdirect attention from these key programs. When Bechtel and General Electric can construct a light water nuclear plant in Taiwan in 5 years, and it takes them twice as long to construct the same plant in Mississippi; when the Japanese and the French, using American technology and designs, can routinely construct lightwater plants on well-defined schedules 40 percent shorter than ours at substantially lower costs; and when nuclear plants are canceled in New England and arrangements are proposed to import nuclear-generated electricity from Canada, then the situation would seem to transcend the particulars of nuclear technology and perhaps nuclear power itself.

So we ought to keep in perspective that these new plants are plants that we should be developing for our children, and they are not remedies or means to revive nuclear power in the United States today. And, indeed, it seems to me, unless we address the present problems of nuclear power today, it's going to be hard to find a base upon which to introduce these new plants.

For the nearer term I'd mention the high-temperature modular reactor—or the high-temperature gas modular reactor—and the modular breeder reactor. For the nearer term it seems to me it would appear worthwhile to explore improving some of our lightwater reactor designs.

Before, however, getting overly excited about rather new, exotic-type lightwater concepts, such as the PIUS reactor, which it seems to me is going to take major development efforts, one might look to the development of improved lightwater reactors along more conventional lines. It has, after all, been a decade since there has been serious work on new lightwater reactor designs for the United States. In the coming years it may well be that the U.S. environment will require smaller increments of added nuclear capacity, both because of lower electrical growth rates and because of risk aversion.

Such a concept as a natural circulation, boilingwater reactor with a simplified design to meet today's regulatory needs may be an appealing—may not be appealingly adventuresome, and in a sense is a return to the past, but it may well be a way to help the nuclear industry technologically in the not too distant future.

Madam Chairman, I very much appreciate the opportunity to make these comments. As I indicated, we believe that advanced technology for the future is important to the welfare of the Nation, but we ought not to lose perspective and ought not to take our focus off the need to correct the problems of the present, to provide a base upon which the future work can proceed.

Thank you very much.

[The Prepared statement of Dr. Wolfe follows:]

PREPARED STATEMENT OF BERTRAM WOLFE, VICE PRESIDENT AND GENERAL MANAGER, NUCLEAR FUELS AND SPECIAL PROJECTS DIVISION, GENERAL ELECTRIC CO.

Madam Chairman and other Members of this Subcommittee:

My name is Bertram Wolfe. I am a Vice President of the General Electric Company and General Manager of its Nuclear Fuel and Special Projects Division. I received a Ph.D. in Nuclear Physics from Cornell University in 1954 and have been in the nuclear power business for over 25 years, two-thirds of which have involved advanced reactor development. I am a professional engineer in California, a Fellow of the American Nuclear Society, a member of the National Academy of Sciences, and the author of several dozen papers on nuclear energy and nuclear technology. I want to thank the Subcommittee for your invitation to participate in these important hearings.

Although the topics covered in these hearings may all be grouped under the title, "Advanced Reactor Programs," I believe it important to recognize that in fact three separate subjects are involved. The first, mentioned in the Chairman's letter of invitation, is "the role which the Advanced Reactor R&D programs can play in reinvigorating the nuclear power option." The second is the role of nuclear power in special applications such as space power, and remote terrestrial applications. And the third is the development of advanced nuclear power plants for application in the future. I plan to address the first and third subjects today. It seems that at times these subjects become intertwined and confused. Such confusion can in my opinion be counterproductive to reinvigorating nuclear power in the U. S.

As we have learned recently with the Clinch River Breeder project, and in the past with light water reactors, gas reactors, sodium graphite reactors, heavy water reactors, organic cooled reactors and so on, the development of a new reactor concept to commercial practicality is a time consuming and costly endeavor. In the United States today the costs range in the billions of dollars, and the time scale in decades. Furthermore, as we have learned from today's commercial power reactors, even after economic practicality has been reached it may take 20 years or more to find that steam generators fail more often than expected, that pressurizer's instrumentation may give misleading indications as it did at Three Mile Island, that 304 stainless steel is susceptible to stress corrosion cracking in boiling water reactors, that radiation damage to pressurized water reactor pressure vessels is more severe than anticipated, that pressure tubes in heavy water reactors can catastrophically fail due to hydriding, or that carbon dioxide in gas reactors can cause adverse corrosion in structural members. It would be foolhardy not to expect some similar revelations as new reactor concepts are developed and deployed.

The advantage of the light water reactors is that a meaningfully large number of them have gone through a major part of their first life cycles and the technical problems which have been uncovered all seem correctable.

It will be decades before a similar statement can be made about the advanced concepts. Thus, arguments that advanced reactors can solve the present problems of nuclear power in the U.S. are misleading because of the uncertainty of success and the costs and time scale. They are also misdirected because they tend to take attention away from the key problems.

No reactor can tolerate bad welding in critical areas, poor electrical work, or other lapses in quality control. No reactor can afford the economic penalties of schedules artificially lengthened to match utility cash flow restraints rather than efficient construction. It would be difficult in any major construction activity to successfully pass the baton through the complex relationships which frequently exist in nuclear projects between the utility owner, the architect engineer, the reactor manufacturer, the consultants, other suppliers, and the regulatory inspectors. And in my view, most serious of all, no reactor system (or other power source) can be successful or even survive in a regulatory system with ever changing groundrules imposed with little predictability so that schedules cannot be maintained, and designs can't be frozen, and under conditions such that even when the plant is built, as in the case of Shoreham in Long Island, one is not sure whether it will be allowed to operate. Indeed, even after a plant has run the gauntlet and successfully reached operation, a la St. Lucie 2, one is not sure if an identical plant could repeat the performance.

These are the institutional impediments to a successful nuclear option. Arguments that our present problems can be corrected by new reactor concepts misdirect attention from these key problems. When Bechtel and General Electric can construct a light water nuclear plant in Taiwan in five years, and it takes them twice as long to construct the same plant in Mississippi; when the Japanese and the French, using American technology and designs, can routinely construct light water plants on well-defined schedules 40% shorter than ours at substantially lower costs; and when nuclear plants are cancelled in New England and arrangements are proposed to import nuclear generated electricity from Canada; then the situation would seem to transcend the particulars of nuclear technology and perhaps nuclear power itself.

The above discussion is intended to place some perspective on the subject of advanced reactors and the present status of nuclear power in the U.S. But it does not address the third subject, namely the development of reactors for the future. How, when, and whether nuclear power revives in the United States is presently unclear. Work on advanced concepts must thus be based to some extent on faith that the nuclear option will be needed in the future, and that there is a responsibility to attempt to improve on present technology for those who follow us. I believe there is basis for this faith. In the first quarter of the next century the world's population will double to 8 billion people, while conventional supplies of oil and gas are being depleted. Six billion of the world's population will be in underdeveloped nations. The United States, with its relatively stable population and its large coal supplies, could in principle do without nuclear power if it were willing to greatly expand its use of coal. However, in view of the known concerns about the use of coal, it is questionable whether the U. S. should or would become so overly dependent on a single energy source for electricity and other uses. In most of the rest of the world where population and energy needs will be greatly increasing and where coal is a distant non-indigenous resource, the appeal of nuclear power is of course much greater. The inevitable conclusion from this simple analysis is that despite its present problems it would be a mistake to rule out an accelerating use of nuclear power worldwide in the future. Thus, it would seem in the national interest to devote effort towards improved nuclear technology for this future.

For the near term it would appear worthwhile to explore improvements in light water reactor design. However, before getting overly excited about rather exotic new light water concepts such as the PIUS reactor, one might look to the development of improved light water reactors along more conventional lines. It has, after all, been a decade since there has been serious work on new light water reactor designs for the U. S. In the coming years it may well be that the U.S. environment will require smaller increments of added nuclear capacity, both because of a lower electrical growth rate and because of risk aversion. Such a concept as a natural circulation boiling water reactor with a simplified design to meet today's regulatory needs may not be appealingly adventuresome, and in a sense is a return to the past, but it may be a way to help the nuclear industry technologically in the not too distant future.

In past discussions with committee staff members and the Department of Energy, we have described some thoughts on advanced reactors which might be available for the more distant future. In these discussions we have indicated that if the breeder is to be developed in the United States, it will be by following the modular approach that we have been working on with the Department of Energy. This is not necessarily because the modular reactor is inherently better than a well-developed large thousand-to-fifteen hundred megawatt design (although it may be), but because its development costs may be affordable. The same comment applies to the modular high temperature gas reactor for process heat on which we have been working with the Department of Energy. These reactor types can make major contributions in the future; the breeder because it can provide an unlimited supply of nuclear fuel and energy, and the HTGR because it can provide process heat at temperatures otherwise unavailable from nuclear power. But, of course, development of such reactors for the future will not remedy the present state of nuclear power in the United States. For this emphasis must be placed on improving the institutional situation outlined above and light water nuclear reactor systems so as to establish a base of credibility for the future.

Madam Chairman and Subcommittee Members, I hope the comments above are of use to you.

Mrs. LLOYD. Thank you, Dr. Wolfe.

I would like to remind you that this administration would not allow any R&D funding for any LWR improvements; that we are a research and development subcommittee and we do not doubt the validity or the need for the LWR's, the LMR's. And, as I said this morning, I don't think anybody can doubt my steadfastness in the liquid metal program. But, at the same time, we must address the problems and things that we can do today in the field of research and development as a jurisdiction for this subcommittee as well.

Dr. Till?

STATEMENT OF DR. CHARLES E. TILL, ASSOCIATE LABORATORY DIRECTOR, REACTOR RESEARCH AND DEVELOPMENT, ARGONNE NATIONAL LABORATORY

Dr. TILL. Madam Chairman, I'm Charles Till, associate laboratory director for Argonne National Laboratory. I'm responsible for the laboratory's reactor research and development program.

I appreciate the opportunity to speak to the subcommittee about the future course of breeder reactor development in the United States, and, in particular, to describe an advanced breeder concept that I believe can provide the technical basis for resolution of many of the issues faced by the breeder today.

The concept was developed within the recent thrust of the Department of Energy toward innovative breeder design. Our objective was to see what could be done with recent advances in technology to resolve some of the issues that today cause so many people concern about the breeder, because as a general concept the breeder is fundamentally sound. It can provide inexhaustible energy supplies and its technological feasibility is certain.

Mrs. LLOYD. And I agree with you.

Dr. TILL. Amen.

These facts should not be lost—that fact shouldn't be lost in debate about the particular form of the breeder. But it is also true that unless the particular breeder concept we adopt provides the technological basis for meeting today's concerns, the entire option may be lost to this Nation.

I believe that the advanced breeder concept that I will describe today goes a long way toward providing such a basis.

The concept is the integral fast reactor. It is called integral because all the facilities necessary for a truly complete breeder system are integral to and part of the plant—the reactor, the fuel cycle, the waste treatment. Some very important simplifications are achieved.

As a basic concept, it isn't new. In fact, the concept was the goal of the earliest directions of breeder development in this country. Those directions culminated in the construction of the EBR-II concept—or complex—on the Idaho site, which went into operation in 1964. But the extension at that time to a practical system just wasn't possible with the technology of that time. It is now. Technological advances in the past few years have provided the means for solving the difficulties that blocked the earlier development. It is the realization that this is so, and the way all the pieces fit together to give a simple and complete breeder system, that is new.

Now the advances that make the IFR possible are in the areas of metal fuel burnup, which is about 10 times what was thought to be possible then; metallic reprocessing—there are two separate advances from the early EBR-II process that now allow complete recovery and recycle of the fuel; and, also, adequate removal of all the fission products. Those things were not possible then.

Further advances in reactor safety technology take advantage of the intrinsic properties of the system, and that is to say the breeder, the sodium cooling part of the breeder system, and also the high conductivity of the metal fuel to give it superior and inherent safety characteristics.

So the IFR is based on three individual concepts:

One, it's a pool.

Two, it's metal fuel.

Three, it's metallic reprocessing; that is, the reprocessing and refabrication is kept in metallic form at all times. No change of form, no dissolution, et cetera.

The reactor has the following characteristics: It has some appealing nonproliferation properties. It eliminates all plutonium flows. There's no transportation problem. No plutonium ever need enter or leave the plant. And that one feature may be of overwhelming importance to a realistic deployment of plutonium-fueled systems.

Diversion resistance: The fuel, when out of the reactor, is processed remotely and is deadly radioactive at all times. More than that, practically the whole of the fuel inventory is in the reactor, with a small fraction outside ever.

There's no plutonium supply problem. The breeding properties of metal are so good that we can start this system with U^{235} and it will be self-sustaining for the rest of its lifetime.

It's got a very high level of inherent safety. The combination of the high thermal inertia of the pool plus the high conductivity of metal gives an array of safety characteristics that really are highly appealing. As you go right across the whole range of possible accidents in a breeder from the most minimal to the most extreme, this concept retains all the advantages of the present breeder. It's got superior characteristics in many regards, and in one or two key events it has huge advantages.

Reduced costs: The concept allows great reductions in size, and also in construction commodities and schedules. How low the costs can be made I don't know, and we won't know until we have a detailed design of the whole system.

Mrs. LLOYD. Do you have a ball park number?

Dr. TILL. I don't, no; on the pool aspects of it, bringing the costs down somewhere in the range where you can see the LWR cost, but the cost of the overall system I don't know. What I can say is that the reprocessing-refabrication part of the plant is extraordinarily simple, and we believe it will be very cheap.

I have some estimates on what it would cost to demonstrate, but I don't have an optimized plant. We won't have until we can proceed.

In the waste——

Mrs. LLOYD. Excuse me, Doctor. Could you submit this for the record?

Dr. TILL. Yes; indeed I will.

Mrs. LLOYD. Thank you very much.

[The information follows:]

The objective of IFR development and demonstration is to prove feasibility first, and then completely demonstrate it on a realistic scale, quickly and inexpensively. It can be done within overall levels of breeder base program funding similar to fiscal year 1984, without inordinately affecting the present breeder development program. It mainly requires reprogramming within the technology elements of the base program and extensive use of the existing Argonne-West facilities.

The basic aim is to establish the IFR basic feasibility and promise in two years, and to demonstrate the concept on a realistic scale in the EBR-II complex within five years. At the end of the five year period, the following would be accomplished:

a. Complete demonstration of the IFR concept in the EBR-II complex—including EBR-II fueled with the reference metal fuel and the Integral Fuel Cycle Facility (IFCF) in operation.

b. Detailed design of a reference IFR plant will be completed to the point where realistic economic evaluations can be made.

c. Development of the IFR concept adapted to single-unit low-cost demonstration plant in conjunction with the IFCF.

Funding requirements, incremental over the fiscal year 1985 President's budget, are $33,160K for fiscal year 1985, and $37,200K fiscal year 1986, at the end of which time the feasibility would be proven.

A line item for the modification of the EBR-II complex to incorporate integral fuel cycle reprocessing and fabrication would be submitted for the fiscal year 1986 budget. An early estimate for the cost of this is $45,200. When completed this facility would give sufficient capacity for full recycle in EBR-II, plus enough capacity to handle a CRBR-size demonstration plant later, if a later decision were to be made to proceed.

Operating funding increments required in the out years fiscal year 1987 and fiscal year 1988 are in the range to $25 to $30M per year (i.e., less than that required in fiscal year 1986.)

Dr. TILL. In the waste area, as the fuel processing is metal throughout, the volumes are very small, and the high level waste can go directly to glass. The volumes are small enough you could store them on the site for the whole plant lifetime.

It's flexible in size because the reprocessing and refabrication goes right along with the plant. There is no need for a large, central reprocessing plant feeding a lot of reactors.

That brings me to the last point. I believe if you put those characteristics together, if you put them together, you can see that it's ideally suited to power parks of a reasonable size, 2 gigawatts, today's sizes. And that, I think, to me, for the first time gives a realistic kind of notion of how the breeder could really be deployed. You could make this a self-contained enclave if you wanted to. As I say, no fuel is ever entering or leaving.

Madam Chairman, attached to my statement is a report that elaborates more fully on the points that I have discussed, and I do submit it for the record.

Thank you.

[The prepared statement of Dr. Till follows:]

Prepared Statement of Charles E. Till, Associate Laboratory Director, Reactor Research and Development

Madam Chairman, and Members of the Subcommittee, I am Charles Till, Associate Laboratory Director of Argonne National Laboratory, responsible for the Laboratory's Reactor Research and Development Program. I appreciate the opportunity to speak to the Subcommittee about the future course of breeder reactor development in the U.S. In particular, I appreciate the opportunity to describe an advanced breeder concept that I believe can provide the technical basis for the resolution of many issues faced by the breeder reactor today.

This concept was developed within the recent thrust of the Department of Energy toward innovative breeder design. Our objective was to see what could be done with recent advances in technology to resolve the issues that today cause so many people concern about the breeder, some to the point of total opposition, even among those who are otherwise favorably disposed toward nuclear power.

As a general concept though the breeder is fundamentally sound -- it can provide essentially inexhaustible energy supplies and its technological feasibility is certain. That fact should not be lost in debate about the particular form the breeder should take. But it is also true that unless the particular breeder concept we adopt provides the technological basis for meeting todays concerns, the entire option may be lost to this nation.

I believe that the advanced breeder concept I shall describe to you today goes a long way toward providing this basis.

The concept is the Integral Fast Reactor (IFR). It is called Integral because all the facilities necessary for a truly complete breeder system are integral to and part of the plant -- reactor, fuel cycle, waste treatment. Very important simplifications are achieved.

As a basic concept, it is not new. In fact this concept was the goal of the earliest directions of breeder reactor development in this country. Those directions culminated in the construction of the EBR-II complex on the Argonne site in Idaho, which went into operation in 1964. But the further extension to a practical system was just not possible with the technology of that time. It is now. Technological advances in the past few years have provided the means for solving the difficulties that blocked the earlier development. It is the realization that this is so, and the way all the pieces fit together to give a simple and complete breeder system, that is new.

The advances that make IFR possible are in the areas of metal fuel burnup capability (about ten times what was thought to be feasible then); metallic reprocessing (two separate advances from the early rudimentary EBR-II process now allow complete recovery and recycle of the fuel, and adequate removal of all important fission products); and advances in reactor safety technology that take advantage of the intrinsic properties the system possesses to give it superior and inherent safety characteristics.

The IFR is based on three individual concepts.

1. All nuclear systems and radioactive elements are immersed in a large pool of liquid sodium coolant.

2. The fuel is metal. It has high performance in power, burnup, and safety capabilities,

3. The fuel is decontaminated, reprocessed and refabricated in a simple procedure right beside the reactor. It stays in metallic form throughout the process.

The IFR has the following characteristics:

1. Non-Proliferation Properties: The concept eliminates all plutonium flows. There is no transportation problem. No plutonium ever need enter or leave the plant. This one feature may be of overwhelming importance to realistic deployment of plutonium-based fuel cycles.

2. Diversion Resistance: The fuel when out of the reactor is processed remotely and remains deadly radioactive at all times. Further, all but a relatively small fraction of the fuel is actually in the reactor at all times and completely inaccessible.

3. No Plutonium Supply Problem. The breeding properties of metal fuel are so adaptable that the concept will start up on uranium-235 fuel, and as lifetime proceeds, build in its own plutonium sufficient to make the reactor self-sufficient without any additional feed.

4. High Level of Inherent Safety: The combination of the large thermal inertia of the cool sodium pool and the excellent conductivity of metal fuel gives superior safety characteristics that are both intrinsic to the materials and easy to identify. Over the full range of conceivable accident conditions, the concept retains all the advantages of today's breeder designs, in some situations it is considerably better, and in a crucially important few cases it gives huge benefits.

5. Reduced Costs: The concept allows great reductions in size, and therefore in construction commodities and costs. Further it is based on an array of fundamental simplifications, all leading to cost reductions. How low the costs can be made must await detailed design and optimization of the concept but enough has been done to be certain that the potential for competitive economics is very real.

6. Waste Problem Solution. As the fuel processing is metal throughout, all volumes, including the waste, are small and compact. The solid fission products making up high level waste are encapsulated directly in glass. The gaseous fission products are captured in the first stage of the process. There are no effluents.

7. Flexible in Size and Capacity: The entire plant is physically compact, and the fuel cycle facilities themselves are small and scale naturally to the plant capacity.

8. Feasible Ways of Deployment: The whole concept is designed for adaptation to power ~~parks~~ Parks of reasonable size -- a few thousand megawatts; similar to those of large utilities today, and to economic incremental addition of capacity. Today both features appear to be necessary for successful deployment of any nuclear reactor system. For the breeder, however, these features plus the elimination of transportation, point to a feasible path to breeder deployment, perhaps for the first time. Further, under these circumstances the entire power park could be made a safeguarded enclave, if desired.

As is evident, each individual characteristic has the potential for solution of an important problem facing the breeder. In combination, I believe, they represent a very substantial advance over today's reactor technology.

Madam Chairman, attached to my statement is a report that elaborates more fully the points that I discussed, and I submit it for the record. Thank you.

AN ADVANCED BREEDER CONCEPT: THE INTEGRAL FAST REACTOR

CHARLES E. TILL

Associate Laboratory Director
Reactor Research and Development
Argonne National Laboratory

A report supplementing testimony before the
Subcommittee on Energy Research and Production
Committee on Science and Technology
U.S. House of Representatives

February 8, 1984

THE INTEGRAL FAST REACTOR

Recent technological innovations make possible an advanced breeder reactor system that is at once inherently safe, less expensive than previously achievable, and which has a closed, economic, self-contained and highly diversion-resistant fuel cycle. This new concept is the Integral Fast Reactor (IFR). It consists of three elements:

- A pool-type sodium-cooled reactor.
- A compact fuel cycle facility sited as an integral part of the reactor plant, thus eliminating all external plutonium flows.
- A metal-alloy reactor fuel, which the fuel cycle technology requires and which provides inherent safety advantages.

The concept preserves the long-standing advantages of the breeder, but goes much further in providing a basis to resolve the major problems that nuclear systems face today.

From the start of fast reactor development, key benefits were recognized. First, it was postulated and later proven beyond doubt that such reactors can be designed to produce more fuel than they consume, i.e. to "breed". This allows an essentially inexhaustible fuel supply, and has been the principal rationale for breeder development. With today's expectation of a protracted deployment schedule for any new nuclear system, breeding characteristics seem less important. Nevertheless, the measure of success of any energy development program is in the magnitude of the energy it ultimately produces, and breeders are the only nuclear systems that can produce energy essentially without limit. Secondly, the use of sodium coolant provides the basis for a number of advantages in inherent safety, such as a large margin to boiling, atmospheric pressure heat transport systems, and strong natural circulation capability.

The IFR retains these intrinsic features, but in addition gives promise to resolve major problems that confront all nuclear systems:

- high and uncertain plant costs,
- perceptions of inadequate safety,

as well as a long-standing problem for the breeder that until now seemed very difficult:

- the requirement for a complete fuel cycle, in an uncertain deployment situation with serious safeguards and transportation concerns.

The fundamental pieces of the IFR concept have a firmly established technological basis. Argonne National Laboratory has operated the Experimental Breeder Reactor-II (EBR-II) for the past twenty years. It has proven to be a highly reliable 20 MWe pool-type reactor plant, achieving a plant capacity factor of 72% over the past five year period even with the frequent outages required to fulfill its experimental mission. Performance of the metal alloy fuel used in EBR-II is at least equal to that of the highly-developed oxide fast reactor fuel. The fuel fabrication technology required in the IFR is essentially identical to that currently used for EBR-II. The reprocessing technology required for the IFR has its basis in an elementary form demonstrated at EBR-II, with a key new additional reprocessing step based on defense program experience. Thus the realization of the IFR relies on technological advances already made, not on development of new technology.

This report discusses the following characteristics of the IFR concept:

- competitive plant cost,
- inherent safety,
- high-performance fuel,
- integral fuel cycle,
- non-proliferation features,
- flexibility in deployment,
- inexpensive demonstration.

COMPETITIVE PLANT COST

Over the past two years, Rockwell International and Argonne National Laboratory have been jointly developing an innovative pool plant design, with significant contributions from other industrial organizations. The conceptual design led to the conclusion that the pool type arrangement is the key to accomplishing competitive plant cost, reduced construction schedule, reliability/maintainability and inherent safety.

The pool plant design differs from the loop-type plant primarily in the primary system configuration. In the pool design, the entire primary system including intermediate heat exchangers and primary pumps is submerged in a large pool of relatively cool, atmospheric pressure liquid sodium contained in a single reactor vessel. The elimination of complex primary piping and associated support systems and inerted housings for intermediate heat exchangers and pumps results in a very compact, simplified reactor containment building and nuclear island arrangement. Comparisons of nuclear island bulk construction materials indicate reductions by a factor of two from conventional loop-type LMFBR designs or from standard PWRs. Furthermore, the lesser quantities of construction commodities, combined with reactor system design simplifications, facilitate rapid construction. In-containment congestion is reduced and in-vessel welding is eliminated which results in a significant reduction in construction schedules.

Although the reduction of construction commodities and building sizes is the most direct cost reduction avenue, there are other intrinsic performance characteristics that contribute toward further cost reduction. For example, highly reliable decay heat removal is easily achieved in the pool design by passive systems and natural circulation, independent of the normal heat transport systems. This allows intermediate heat transport systems to be nonsafety grade, resulting in significant cost savings.

The large thermal inertia of the cold sodium pool itself is a key factor in inherent safety, but it also gives reduced thermal coupling between primary and intermediate heat transport systems. This allows a simplified plant protection system, a reduced number of trip sensors, and a reduction in emergency power requirements. The insensitivity of the reactor system to transients originating in the balance of plant allows construction of the latter to non-nuclear standards.

In addition to the fundamental simplifications and resulting cost reduction, pool plants have also demonstrated high reliability and maintainability. And since sodium is noncorrosive and compatible with structural materials, and the entire radioactive sodium inventory is contained in the reactor vessel, pool plants give very low occupational exposure levels -- an order of magnitude less than for LWRs.

We therefore concluded that the basic system configuration of the concept must be a pool.

INHERENT SAFETY

A major driving force in the development of the IFR concept was to specifically identify characteristics that increase inherent safety and to incorporate them into the design. In addition to the generic features common to all fast reactors that provide inherent safety, the pool concept has been exploited to provide additional inherent safety characteristics. Also, the use of metal fuel provides an appreciable increase in inherent safety. The total concept provides a very high level of inherent safety, probably unequaled in any other reactor type.

Evaluation of inherent safety must consider the entire spectrum of possible reactor malfunctions and accidents. The evaluation proceeds from normal behavior to anticipated transients. It includes consideration of margins to failure. It involves assessment of design basis accidents, of the margins beyond design basis, and of the degree of accommodation and mitigation of even the most severe events.

The IFR concept provides inherent advantages across the entire spectrum. It provides a high level of protection against local faults and their escalation. There is an extraordinary level of accommodation to anticipated transients, where for example, it is not necessary for active components such as the plant protection system to function. There are very large margins before core damage is approached. There is a high level of protection against any untoward events in the event of a single failure of any component. Large margins exist against very unlikely events involving multiple failures (for example, loss of flow with failure to scram). Finally even if a core disruptive event occurs for any reason (even though there is no credible mechanistic path for such disruption) there is a very large degree of mitigation and essentially no public safety impact.

The generic characteristics of sodium-cooled fast reactors that generally lead to high inherent safety are well known and are mainly due to the low-pressure coolant far below its boiling point, and the general compatibility of the various materials comprising the core. These features simplify the inherent safety considerations of fast reactors relative to other systems. In fact, it is only necessary to assure the action of the reactor shutdown system and the decay heat removal system to ensure system integrity and public safety.

But the pool configuration adds another significant dimension to inherent safety. Mainly this comes from the large thermal inertia of the sodium in the reactor pool. This essentially leads to isolation of the behavior of the balance of plant from that of the primary system. In effect, no transients occurring in the balance of plant need require any safety action to prevent damage in the primary system. This simplifies the safety design of the system. Further advantages accrue to the pool system from the clean primary system boundary and the absence of widely distributed primary coolant. Also, the larger volume of the primary reactor vessel facilitates the design of passive decay heat removal systems which are independent of the normal heat transport path.

A number of additional crucially important inherent safety advantages also accrue from the utilization of metal fuel. The metal fuel is compatible with sodium; in fact, sodium is present within the pin to bond thermally the metal fuel to the cladding. One important result is that the possibility of local faults, and their failure propagation, is much diminished. Many advantages follow from the high thermal conductivity of the metal fuel. During overpower or flow transients the reduced thermal gradient within the fuel pin significantly increases margins to failure. In the extremely unlikely event of a loss of primary coolant flow and with a failure to scram, the reduced thermal gradient in metal fuel significantly downgrades the severity of the event. In contrast to other breeder designs, the core outlet temperature rise in this scenario is very small and no core damage results. Finally, in metal fuel the entrapped sodium within the pin appears to provide a fuel dispersal mechanism that plays an important role in early termination of transients that might involve any fuel melting. This benign early termination eliminates concern over recriticality or fuel-coolant thermal interaction, and thus of the possibility of energetic core disruption.

In comparing the IFR with other fast breeder reactor systems, it appears that across the spectrum of potential reactor malfunctions and accidents, the IFR provides equivalent inherent safety in some areas, provides significant advantages for other events, and in a few crucial areas provides a very large margin of increased inherent safety.

The essential conclusions on IFR inherent safety are:

1. There is no transient expected to occur in the lifetime of the plant that requires the action of the plant protection system in order to avoid core damage.

2. There is no single failure in the system that will cause significant core damage even in the event the plant protection system does nct function.

3. In the event of extremely unlikely multiple failures, for example, loss of flow with failure to scram, there is sufficient margin in the system that severe damage is avoided or mitigated. The loss of flow without scram event does not lead to core disruption.

4. Even in the event of core disruption from whatever means (no credible mechanistic path can be defined), the early fuel dispersiveness caused by action of entrapped sodium within the pin would preclude energetics and any significant public safety impact.

The validation of the above conclusions can be made in straightforward experiments in existing facilities.

HIGH PERFORMANCE FUEL

Metal fuel has always been recognized to have superior thermal and neutronic performance. In the early development of the breeder, it was thought that metal fuel had severe burnup limitations in the range of 1 or 2%. These early problems of low burnup limits for metal fuel have now been resolved.

The critical feature in the design of high burnup metal fuel is accommodation of swelling. It is understanding the swelling phenomenon, driven by fission-gas bubble behavior, that has led to high burnup performance of metal fuels. The key item is that after the fuel swells to a volume increase of about 25%, fission gas bubbles begin to interconnect, releasing fission gas to a plenum and removing the mechanism to highly-stress the cladding. By the time a 30% swelling is reached, the fuel is so porous that further outward swelling is easily restrained by the cladding, and subsequent room for solid fission products to build up is provided by gradual closing of the pores. This process has been verified for a variety of metal alloys and each has shown identical fission gas behavior and interconnection of pores. Fundamentally, then, high burnup behavior of metal fuel relies mainly on adequate clearance inside the pin when fabricated. Increased clearance always reduces the neutronic performance, but with metal alloys the densities are so high that over 30% clearance can be provided while neutronic performance still surpasses that of any ceramic fuel.

The EBR-II Mark-II fuel element was designed to take advantage of the phenomenon of interconnected porosity to allow 33% volume swelling of the fuel before fuel-cladding contact. Also, the gas plenum was designed with sufficient volume to keep the plenum pressure due to the released gas reasonably low over the life of the element. Over 150,000 Mark-II fuel elements irradiated in EBR-II demonstrate the adequacy of metallic fuel. Currently Mark-II fuel is routinely discharged at 8.5% burnup, although the limit exceeds 10%. A limited number of elements have attained 18.5% burnup. New Mark-IIA elements with a minor design change are expected to reach about 14% burnup.

In addition to the extensive irradiation data base associated with the reference uranium alloy, a wide range of alternative alloys have been irradiated in EBR-II and the most promising is U-Pu-Zr which is proposed for use in IFR.

This alloy not only exhibits good irradiation performance but provides the additional benefits of an elevated solidus temperature and, in conjunction with stainless steel cladding, an increased eutectic formation temperature. Together these attributes provide a greater temperature operating range and more margin for offnormal events.

The majority of experience has been obtained at EBR-II with metal fuel having a different composition from that proposed for IFR. However, the same mechanisms are known to govern the behavior of the U-Pu-Zr alloy. Hence, a prolonged and expensive fuel development program is not required to demonstrate that U-Pu-Zr alloys possess the excellent performance characteristics experienced with EBR-II driver fuel.

In addition to fuel swelling and gas release, the important phenomena which can affect fuel performance are thermal conductivity, phase stability, fuel-cladding compatibility, fuel-coolant compatibility, and fuel-cladding mechanical interaction. The issues resulting from these phenomena have all been resolved and demonstrated for the uranium alloys for a wide range of steady-state and transient conditions. The addition of plutonium has been demonstrated not to affect the basic behavior of uranium based metal fuels. In particular, the U-Pu-Zr alloy exhibits a higher melting temperature and a higher eutectic formation temperature than alloys that have performed satisfactorily for years.

The strong technology base established for metal fuels when coupled with 20 years of continual development of metallic driver fuels for EBR-II, has resulted in a high level of understanding for these fuels in actual power plant operation. Because this understanding was gained in an operating power reactor, each step of development received a thorough safety review and each step was a proven contribution to the overall plant reliability. This basic understanding of the underlying technology will be applied in the design and operation of the IFR metal fuel.

INTEGRAL FUEL CYCLE

The IFR concept relies on the close coupling between the reactor and the fuel cycle operations needed to support the reactor. The IFR fuel cycle includes a simple, two-step pyrochemical reprocessing operation, ideally suited to the metallic fuel of the IFR. The fabrication of metallic fuel is almost identical to the injection casting used for several years in the EBR-II Fuel Cycle Facility. The volume of wastes from the fuel cycle are small and are processed to stable, disposable forms. All of these operations are carried out in a single shielded facility that is integral to the reactor.

The principal advantages of such an integral fuel cycle are:

- Elimination of off-site fuel shipments.

  All fuel materials are retained on site.

- Quick turnaround of fuel.

  Short-cooled fuels can be processed, thereby minimizing the reactor fuel inventory, associated inventory costs, capital costs for on-site spent-fuel storage facilities, and the doubling time for the reactor fuel inventory.

- Absence of plutonium outside the plant.

  The processing and fabrication of fuel does not require the movement of plutonium into or out of the reactor site.

- High resistance to fuel diversion.

  Diversion of reprocessed and refabricated fuel is highly unattractive since the low removal of fission products inherent in this form of reprocessing results in retention of much of the original radioactivity, therefore making the fuel little more attractive for diversion than the discharged spent fuel itself.

- Process simplicity and economy.

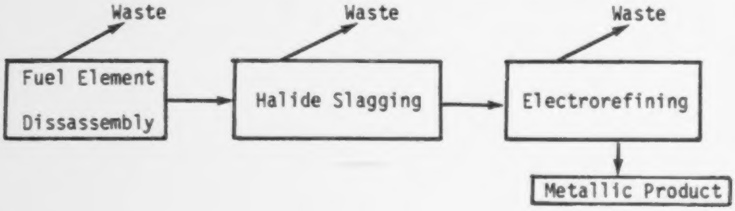
  The pyrochemical process and refabrication both are simple processes with metal fuel. These attributes lead to low fuel cycle costs.

- Simplified fuel fabrication.

  Metallic fuel contains relatively few segments and is produced in a limited number of process steps. Good metallic fuel performance is not dependent on tight fabrication specifications.

An elementary integral fuel cycle was demonstrated by Argonne National Laboratory in the mid 1960s as part of the EBR-II system. For five years, fuel discharged from EBR-II was processed, fabricated, and assembled for return to the reactor in a facility built adjacent to the reactor. This facility is a shielded, circular cell, the process section of which was filled with an inert gas. Quick turnaround of fuel was sought since a major objective of this demonstration was to minimize the doubling time. By using a metallurgical slagging-type process, with all process reagents highly resistant to radiation damage, average fuel turnaround times of 50 days or less were routinely achieved.

The basic IFR pyrochemical reprocessing steps build on the process used at EBR-II. The following simplified diagram illustrates the process.



Discharged fuel elements are disassembled to remove the stainless steel shroud, end pieces, and other hardware. These operations are mechanical and considerable experience is available both from EBR-II fuel processing and also from subsequent work on LMFBR fuel processing over the past ten years or more. The fuel pins are relieved of the contained noble gas fission products that are held in the plenum and the parts of the fuel pin (i.e., axial blankets, core and plenum) are separated mechanically. The noble gas fission product wastes are captured. Waste processing is described below. Since the entire disassembly operation is carried out in closed, vacuum-tight equipment under an inert gas blanket, complete retention of fission products is assured. The blanket fuel is declad by mechanical removal of the stainless steel as was practiced in EBR-II, while the core fuel is chopped into convenient-sized pieces without removal of the more tightly adhering cladding.

The "halide slagging" step of the process takes advantage of the fact that chemical reaction between a molten fuel alloy containing fission product elements and a fused halide (i.e., chloride) salt can be controlled by the composition of the salt. Based on data obtained at Argonne and Los Alamos, the transfer of certain reactive fission product elements (i.e., rare earths, barium, strontium) from the fuel alloy to the salt is executed by addition of an oxidizing chloride (i.e., $MgCl_2$) to the fused salt solvent. The reactions proceed quickly and transfer the fission products from the fuel alloy to the salt. The salt containing the fission products is a waste stream. The fuel alloy is transferred to the second major process step, electrorefining.

Electrorefining is a commonly-used process in which a metal containing impurities is electrolyzed. In that process, the desired metal transfers through an intermediate electrolyte to an electrode where it is deposited in purified form. The conditions in the process are adjusted to retain impurities in the electrolyte or in the original source alloy. In the case of the fuel from the halide slagging step, the electrorefining step uses a molten salt as the electrolyte and a liquid alloy as the source.

Electrorefining has been used for more than twenty years for the purification of weapons plutonium and both basic data and production experience assure the applicability of this technique to IFR fuel alloys. The processing of blanket fuel is expected to produce two streams, one containing largely uranium that is converted to new blanket fuel pins and recycled to the blanket parts of the reactor. The other stream from the processing of blanket fuel is enriched in plutonium that is needed in the core to replace the plutonium lost by fission. Both blanket streams are expected to contain some residual fission product elements and alloying elements. Processing of core fuel will move both uranium and plutonium (together with alloying agents and some fission product elements) to the electrode from which the cleaned fuel is recovered. In the electrorefining step, conditions are arranged so that the fission product elements largely remain in the feed stream and, hence, do not accompany the uranium and plutonium in the product. The residue feed stream is, therefore, also a waste.

The various products from the electrorefining step are consolidated into ingots of metal by simply melting. For core fuel, the plutonium content of the ingot metal is adjusted to the desired level by addition of plutonium obtained from the blanket. The blanket ingot is essentially uranium together with the alloying agent necessary for metallurgical reasons. These ingots are passed to the fuel pin fabrication operations and are used without change as feed to the pin casting step.

The products from the pyrochemical process are adequately purified based on the metallurgical requirements for the reactor fuel. Each of the process steps is, however, only moderately efficient in the removal of fission product elements. Unlike the chemical processes in which the fission product content of the product is reduced by factors of ten million or more, the pyrochemical process is expected to reduce the fission product content of the fuel by a factor of no more than about one hundred. The product from pyrochemical processing is highly radioactive. While the pyrochemical process product composition is acceptable for reactor use, it is intolerable to human beings and, thus, is effectively protected against diversion for clandestine purposes.

The pyrochemical process for IFR fuel produces waste at various stages and in low volumes. Noble gas fission products are collected from the fuel pin plenum and also when the fuel is melted under the halide salt. They will be compressed and held in cylinders; subsequent conversion of these fission product elements will depend on the final form selected as suitable for disposal (e.g., clathrates, ion implant). Iodine will be released from the molten fuel and retained quantitatively in the molten salt cover, based on data obtained at Argonne. The small amount of tritium remaining in the fuel will also be released during melting and will probably join the noble gases.

The fission product elements that constitute the high level waste are in two streams. The fused salt from the halide slagging step will be converted directly to glass by treatment with steam in a small glass-making furnace. The other source of fission products is the low-melting alloy used to hold the feed stream in the electrorefining step. This alloy may be suitable for encapsulation in an inert matrix, e.g., lead, or for conversion to other waste forms that are sufficiently inert to meet expected waste form criteria.

Metallic components of the fuel element, i.e., stainless steel, are compacted and stored in containers that would be suitable for shallow land burial. Process components such as ceramic fume traps and perhaps discarded crucibles are expected to be convertable to high level waste glass.

Fabrication of metallic fuel proposed for the IFR is essentially identical to that developed and used at the EBR-II Fuel Cycle Facility. In that facility, about 35,000 fuel pins were remotely refabricated and returned to the EBR-II reactor. Following the successful demonstration of the integral, remotely operated fuel cycle at EBR-II, remote operation was discontinued and an additional 120,000 metallic fuel pins were fabricated by essentially the same technique.

The design and performance requirements of metallic fuel elements result in relatively simple fabrication operations. As opposed to ceramic nuclear fuels, where many pellets are stacked inside of cladding, metallic fuel consists of a pin of few segments, sodium bonded to the cladding. The number of individual pieces handled in the process is relatively few and thus elaborate automatic techniques are unnecessary. The metallic fuel pin segments are fabricated in a single step by injection casting where molten fuel is injected into Vycor glass molds and quenched. Up to 100 pins are fabricated in a single operation. Upon removal of the fuel from the glass molds the pins are sheared to length. Reject pins and residual alloy are simply recycled back into the next injection casting. No further sizing operations are required because the pin diameters reflect the precise dimensions of the glass molds. Subsequent fabrication operations include loading the pin and sodium into the cladding, welding an end cap on the cladding, and heating and vibrating the completed element to insure a continuous layer of sodium between the fuel pin and cladding.

A number of metallic fuel alloys have been successfully fabricated by the techniques described above, including the uranium alloy currently used in EBR-II, a U-Zr alloy, and the U-Pu-Zr alloy of the IFR. The irradiation performance of metallic fuel fabricated by these techniques has been excellent as evidenced by the high capacity factor for EBR-II and the low incidence of fabrication-related failures. In this sense, therefore, the methods of fabrication are well-proven. The process involves a small number of fabrication steps, all of which have been reliable for both cold and remote operations.

In summary, a brief description of the fuel cycle designed for an Integral Fast Reactor shows many advantages of this concept. The scale of reprocessing by a pyrochemical process is easily matched to the needs of the reactor. The products of reprocessing are inaccessible because of their residual radioactivity but are directly usable to cast new fuel pins. Plutonium from the blanket is used to replace that lost from the core by fission and, hence, no plutonium enters or leaves the reactor plant.

The fabrication of metallic fuel is ideally suited for a single, remote operation that is closely coupled to the rest of the fuel cycle. Scrap recovery in the fabrication process requires only simple remelting of casting heels or rejected pins. The small, compact nature of the reprocessing and fabrication steps lend themselves to deployment that is expected to be more economic than other fuel cycle systems.

FLEXIBILITY IN DEPLOYMENT

The inherent features of the IFR:

- complete, self-sufficient, closed fuel cycle, integral with the reactor power plant,
- applicability to a range of plant sizes,

- ability to startup on uranium alone,
- easily adjustable breeding capability, and
- inherent safeguards advantages of the integral cycle,

provide advantages in deployment flexibility.

Since the fuel cycle for the IFR is inherently a physically compact batch process, it is well suited for a range of plant sizes either at individual sites or in power parks. Furthermore, incremental capacity additions could also be easily accommodated. Low fuel cycle costs do not depend on the existence of a large-scale breeder economy with large, centrally-located reprocessing and refabrication facilities.

Another deployment advantage is that the IFR can be introduced even in the face of uncertainty regarding availability of plutonium. The IFR fuel cycle starts with uranium-235 fuel and sustains itself as the fuel gradually converts to a plutonium/uranium mix.

Finally, the high-density metallic fuel permits the attainment of the highest breeding ratio of any fuel type. Alternatively, by varying the mix of radial blanket versus steel reflector assemblies, the breeding ratio can be lowered to a point where the reactor is just self sustaining. Thus, with no change in design, the breeding capability can be adjusted.

The above flexibilities in size and fuel self-sufficiency enhance the ease of deployment and are ideally suited to power parks of reasonable sizes.

INEXPENSIVE DEMONSTRATION

The essential features of the IFR concept can be demonstrated inexpensively and in a relatively short period of time because much of the technology needed to support the IFR is already in place. Demonstration of the concept can be achieved within several years with redirection of the existing breeder base program and only modest additional funding.

Fundamentally, the IFR concept is based on the EBR-II technology and on subsequent developments in the breeder base program. The full range of experimental facilities needed to demonstrate the attractive characteristics of the concept are already in place.

A full scale demonstration of the fuel cycle is required to completely establish the practicality of the IFR concept. The original fuel cycle facility adjacent to EBR-II, which has been decontaminated, can be re-equipped for this demonstration at relatively low cost. The capacity of the refurbished facility could provide the necessary fuel cycle services to completely demonstrate the process in conjunction with the EBR-II reactor, and also could provide sufficient capacity for a future metal-fueled plant of several hundred MWe.

Biography

DR. CHARLES E. TILL

Associate Laboratory Director
Reactor Research and Development
Argonne National Laboratory

Dr. Till is responsible for the Laboratory's Fission Reactor Program. The program includes work on the Fast Breeder Reactor, the Light Water Reactor and on Nuclear Waste Management. The Fast Breeder Reactor work is by far the largest portion, and it is in fact, the largest single program at the Laboratory.

Dr. Till has a Ph.D. in Nuclear Engineering from the Imperial College, University of London, England. He has worked on a variety of reactor concepts, including the U.K. gas-cooled reactor, the Canadian heavy water reactor, and the U.S. Light Water Reactor. Since coming to Argonne in 1963, he has been deeply involved in the development of the Fast Breeder Reactor.

Mrs. LLOYD. Thank you very much, Dr. Till.

Mr. Young, would you proceed with your testimony?

STATEMENT OF JOHN C. YOUNG, PRESIDENT, INTERNATIONAL ENERGY ASSOCIATES LTD.

Mr. YOUNG. Thank you, Madam Chairman.

I'm Jack Young. I'm president of International Energy Associated Ltd., and am here in the capacity of being the U.S. consultant to ASEA-ATOM for its U.S. activities in the PIUS reactor program.

Since ASEA is a newcomer in the U.S. scene, I'd like to discuss a little bit about the company and its light water reactor background and have some brief comments on the PIUS program.

ASEA-ATOM is part of the ASEA group, which has 50,000 employees and has an annual revenue of $3.5 billion U.S. dollars. ASEA-ATOM is a combined reactor supplier and architect-engineer, which is something that the U.S. suppliers are not. It is the only light water reactor suppliers outside of the United States that developed this technology independent of the United States. It did not come from a license arrangement, as the others have.

It has delivered nine commercial boiling water reactors, the first being in 1972, constructing them in a 5- and a 6-year schedule. The performance has been really quite remarkable. The capacity factor of the ASEA BWR's is the highest in the world. It's 35 percent higher than the U.S. BWR's. With respect to the three BWR suppliers, the 1982 data, its record is 15, 35, and 83 percent higher. At the same time the occupational radiation exposure in the ASEA plants is one-tenth. That is an order of magnitude less than the U.S. BWR and it's one-sixth less than the U.S. PWR.

ASEA is delivering two 1,060-megawatt plants, one this year and one next year, on a 5-year schedule at a cost of $1,400 per installed kilowatt. That includes the total cost of money and the project.

This is in a regulatory environment that is very much like the United States. It's a two-step licensing process. It's in a political and public arena that has the same intense concerns on nuclear power as we have here.

Also, I should point out that ASEA, rather than receiving licenses from the United States, has licensed its current BWR design to General Electric and to Hitachi and Toshiba for the advanced BWR design activities that are ongoing in Japan.

The PIUS reactor is really a light water reactor. It is a PWR that operates at conditions that have been well proven in practice.

The inherent safety features of the PIUS deal with providing core protection without having the engineered safety systems, and these systems are the ones that have had the failure-prone aspects in mechanical and electrical systems.

Also, the PIUS concept does not involve the prompt operator, the prompt human intervention for safety.

The advantages of PIUS to the utility company include getting rid of the engineered safety systems and all the quality assurance problems and complexities that have bedeviled the light water reactor, certainly here in the United States.

It has a very high degree of safety against sabotage, terrorism, malicious intervention. And it would protect the reactor operator against the Three-Mile Island financial problem.

In the PIUS concept the operator attention in the most severe scenario would not have to occur for a week.

At the same time we think that the present light water reactor in the United States is very safe, and it's safe because the NRC and industry worked very hard to make it safe. The issue here is, can we take an inherent safe reactor and make it a commercial success. That's one of the reasons why I'm emphasizing the track record, the very practical commercial success that ASEA has had.

I'll give you a description of the current ongoing U.S. activities in PIUS. The conceptual design by ASEA, including the system descriptions, is nearing completion. They are doing—continuing design studies, safety studies, transient analyses, and there are component systems development activities underway.

The design is being reviewed right now by TVA, by the engineering, design and construction organizations, reactor operations, and the research organization.

The ASEA cost analysis on PIUS will be reviewed by TVA in the first half of 1984.

Parts of the PIUS design are state of the art. The core is. It's operating at very low densities, temperatures, and flows.

The concrete vessel is state of the art. The recirculation pumps, the circulation pumps, are state of the art. There are 50 of them currently in operation in present-day ASEA plants.

But the thermohydraulics area is not state of the art and it does require a development program.

The basic demonstration has already happened at TVA in the Norris Engineering Lab. That is the table-top model that I think you're going to see on one of your trips to TVA.

Mrs. LLOYD. I think I'm going to see that next week.

Mr. YOUNG. Yes, Ma'am.

There are thermohydraulic studies under way in ASEA-ATOM, also at MIT here in the United States, and at the Royal Institute of Technology in Stockholm.

ASEA has committed a multimillion dollar thermohydraulic test loop, and that's under construction now in Sweden. And that's going to be an important part of the verification of the thermohydraulic design.

The steam generator activity is under way. There is a comprehensive design activity, but there's been no experimental verification.

ASEA has contracted—is in the process of contracting now—with a U.S. steam generator manufacturer to review the design activities. However, ASEA does realize that it needs to enter into an agreement with a U.S. steam generator supplier for the conduct of the full steam generator design and approving, and it is looking for that partner at this time.

There are a number of development areas that need to be taken to make this a commercial success. I want to stress commercial success because inherent safety doesn't really mean much if we don't have willing utilities that want to move forward.

We're talking about operability and maintenance, component replacement, inservice inspection, the materials operating in the borated environment of the PIUS, and various mechanical features.

The point that I would like to make here is that it is the ASEA track record in success in the commercial program that gives the confidence that they can realistically and successfully move out in this program.

ASEA has made presentations this past fall to the full Commission of the NRC, to the full ACRS, and did meet with the Harold Denton staff. ASEA did participate in the OTA recent meeting, workshop, on advanced reactor R&D. Out of that, Lars Halle, president of ASEA-ATOM, has taken some positions, and a letter has gone forward to you indicating what their proposed approach would be, considering that they're just starting the dialog with the United States. To put the PIUS into the United States, ASEA would not ask the U.S. Government for any design money for its own activities or its own licensing activities. It would expect that the NRC would handle its own licensing costs, the costs inside the NRC.

At the OTA workshop the number $150 million evolved as a consensus number on technology development, and that number did not arise out of the ASEA contribution. Nevertheless, the ASEA management has considered that number and, as they have indicated to you in a letter which is attached to my statement, that level of effort would allow the development of a full-scale test facility. Testing of a steam-generator recirculating pump combination would complete all the major development items, on completion of that, that test scale, using fossil plant steam, fossil steam, not needing a reactor core.

ASEA could sit with the U.S. utilities and other institutions and determine what the terms and conditions for a commercial offer would be. At that point, which would not be very far downstream, a decision would be made. "Well, do we need a demonstration reactor or not? They're not saying that they do or do not?" It would be a point to be examined.

ASEA recognizes it needs a U.S. partner, and it also says that that $150 million would be spent in the United States, or substantially spent in the United States. And, so——

Mrs. LLOYD. What did you say the United States, the R&D portion, would be?

Mr. YOUNG. The $150 million. It was a consensus number that evolved out of the OTA workshop. ASEA has taken that number of a week ago and considered what progress would happen, and the progress is considerable: The full-scale testing of a complete module, steam generator, recirculating pump, and all major development items, sufficiently done that then ASEA comes forward and says, "We're ready to consider a commercial contract." Remember, these are commercial people.

And at that point they would discuss with industry what the terms and conditions would be and do we need a demonstration plant or not. That could happen very quickly.

And my final remarks, Madam Chairman, are that it's time for ASEA, I think, for the management, to come to principals and have these discussions. They have worked with Oak Ridge, and

TVA has agreed, and ASEA has agreed with TVA, to pass the design information it holds to Oak Ridge for its evaluation activities.

And that concludes my remarks, Madam Chairman.

[The prepared statement of Mr. Young follows:]

PREPARED STATEMENT OF JOHN C. YOUNG, PRESIDENT, INTERNATIONAL ENERGY ASSOCIATES LTD. (IEAL)

Madam Chairman and Members of the Subcommittee:

I am privileged to appear before your Committee to comment upon the role which the advanced reactor R&D program can play in re-invigorating the nuclear power option. My comments will address principally the PIUS (Process Inherent Ultimate Safety) Reactor Program.

First, I want to provide some background for my comments. IEAL and its principals have experience dating from the world's first commercial reactor plant and the nuclear navy. We have been and are actively supporting present-day LWR programs in the U.S. and several foreign countries. IEAL developed the research program behind the U.S. Department of Energy (DOE) regulatory reform legislation proposal. We assist nuclear utility companies in LWR design, construction and operation and maintenance programs. We participate in the NRC Quality Assurance Review Group. We represent utilities in public utility commission proceedings related to nuclear plant funding issues. We assist the Institute of Nuclear Power Operations (INPO) in the development of its International Program. We participate in the Atomic Industrial Forum (AIF) Study Group on Revitalizing the Nuclear Option. IEAL has a significant commitment to the success of the current LWR programs as they are conducted around the world. We view advanced reactor R&D programs such as PIUS from this vantage point.

IEAL is the U.S. consultant to ASEA-ATOM of Vasteras, Sweden for the PIUS Reactor Program. My comments today will outline the background of ASEA-ATOM and its LWR program and provide information on the PIUS design and development program, including the ASEA activities in the U.S. ASEA has a mature and successful LWR history, and the PIUS design is drawn from the success of that program.

ASEA-ATOM is a private company, part of the ASEA Group, a company with 50,000 employees and $3.5 billion annual revenues. ASEA-ATOM chose to develop its own reactor technology, following a regulatory regime similar to that of the U.S., including significant public and political concerns as in the U.S. ASEA-ATOM is the only non-U.S. LWR reactor supplier which did not obtain its technology through a license arrangement with a U.S. supplier. In this environment, ASEA has developed a remarkable record. As seen in Figures 1 and 2, ASEA has delivered its plants on time under five to six year construction schedules, using a two-step licensing process similar to the U.S. Figure 3 shows that ASEA plants have the highest BWR capacity factor in the world (35% higher than the U.S. BWR; 15%, 35%, and 83% higher than the three U.S. PWR manufacturers). Figure 4 shows that the ASEA plant Occupational Radiation Exposure is about one-tenth that of a U.S. BWR and one-sixth that of a U.S. PWR. ASEA expects to deliver two 1060 MWe plants on time (five year schedules) in 1984 and 1985 at a cost of $1400/kw, including cost of money. The existing ASEA BWR design concepts are being licensed to General Electric, Hitachi and Toshiba for incorporation in the advanced BWR design being developed by that team for the Japanese. Unlike the U.S. reactor suppliers, ASEA is a combined reactor supplier and architect/engineer, a desirable combination for nuclear projects.

FIGURE 1

ASEA–ATOM BWR Nuclear Power Plants

Plant	Size MWe (net)	ASEA–ATOM Scope of Supply	Delivery Year	
Oskarshamn 1	440	Turnkey	1972	Delayed (RPV)
Oskarshamn 2	580 x)	Nuclear Island	1974	On time (increased service time compensated by reduction of fire consequences)
Ringhals 1	750	Nuclear Island	1973	On time (Buildings and turbines delayed not ASEA–ATOM responsibility)
Barsebeck 1	580	Nuclear Island	1975	On time (51 months) xx)
Barsebeck 2	580	Nuclear Island	1977	On time (52.5 months) xx)
Forsmark 1	900	Nuclear Island	1980	Final delivery date 2 months ahead of schedule
Forsmark 2	900	Nuclear Island	1981	2 months ahead of schedule
TVO I	660	Turnkey	1979	Ahead on time (Strikes and fire not ASEA–ATOM responsibility)
TVO II	660	Nuclear Island + Turbine Island	1981	Delayed (generator)
Forsmark 3	1060	Nuclear Island	1985	On time
Oskarshamn 3	1060	Nuclear Island	1986	On time

x) Power level increased 6% 1982

xx) From start civil construction work to commercial operation

1982-12-30

ASEA-ATOM

FIGURE 2

OSKARSHAMN 3 - CONTRACTUAL TIME SCHEDULE
Time from start concrete work to power operation: 63 months

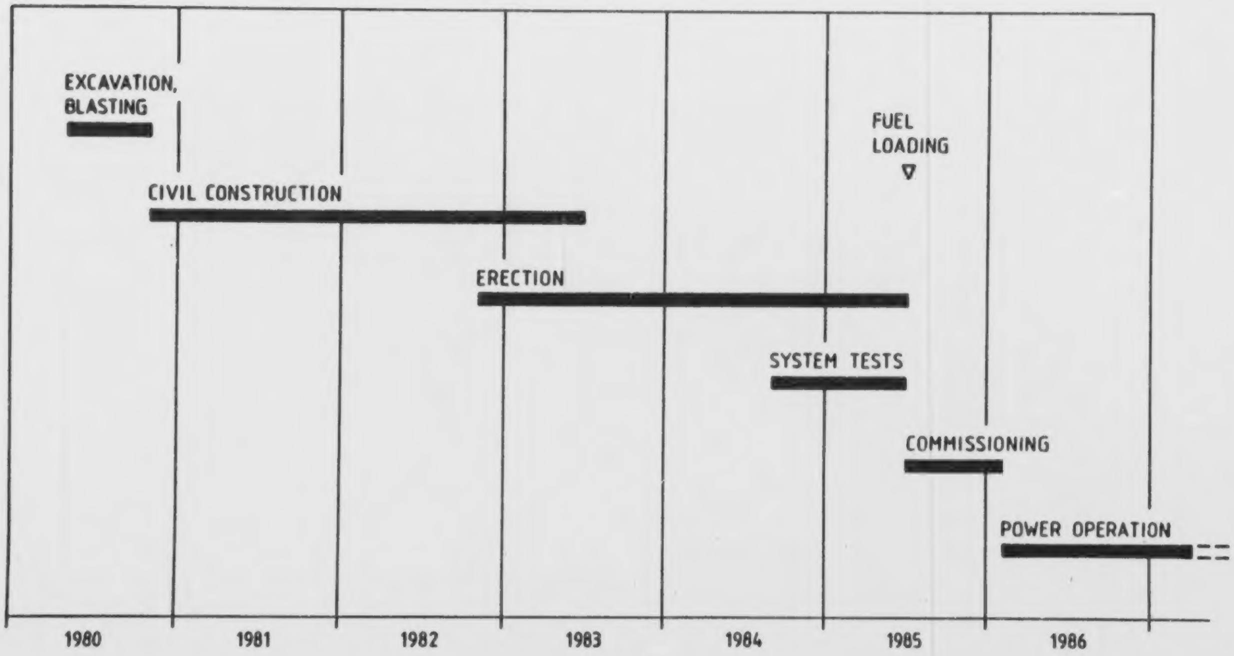
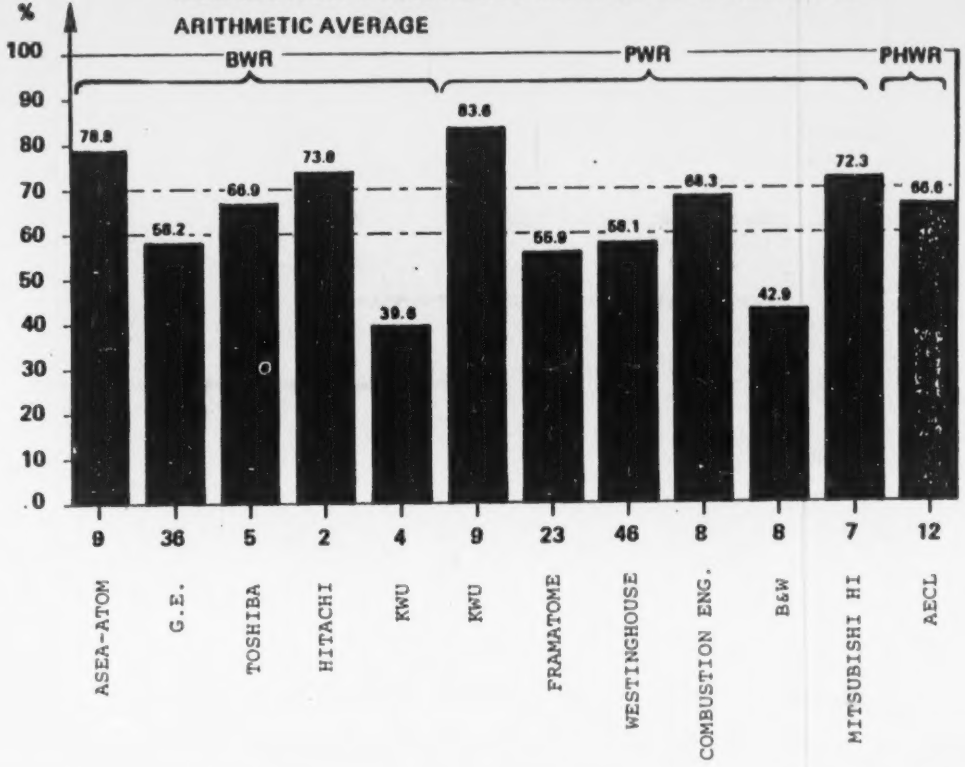


FIGURE 3

1982 CAPACITY FACTORS FOR REACTOR SUPPLIERS



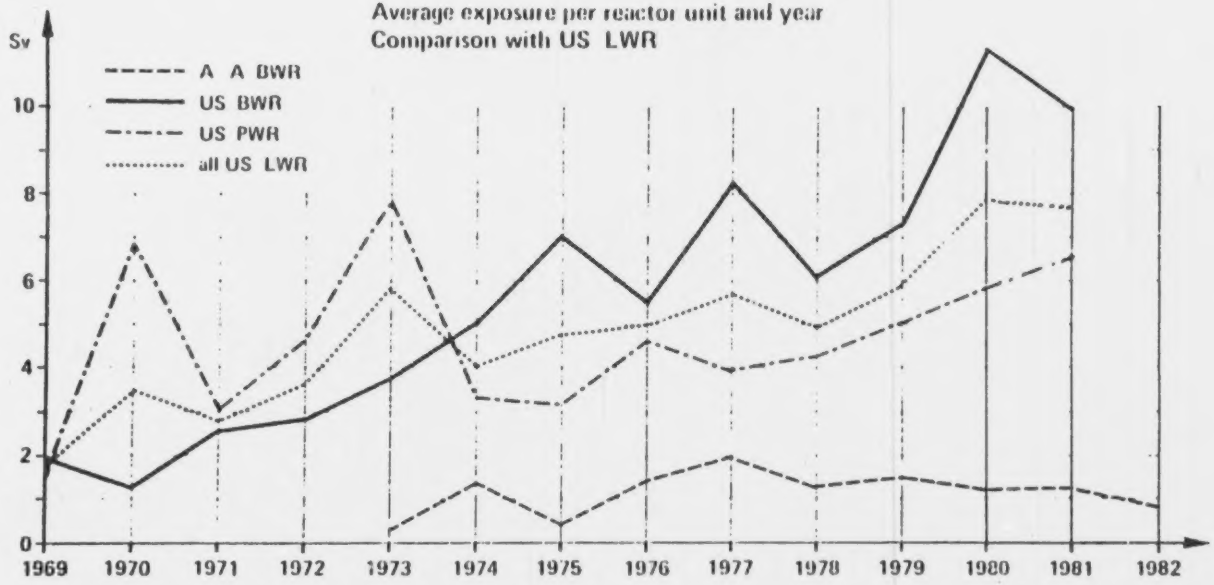
SOURCE:
NUCLEONICS WEEK

ASEA-ATOM

FIGURE 4

ASEA–ATOM BWR – OCCUPATIONAL RADIATION EXPOSURE

Average exposure per reactor unit and year
Comparison with US LWR



The average is based on all reactors which have been in commercial operation for at least one year.

1 man-Sv = 100 manrem

ASEA-ATOM

ASEA-ATOM has an outstanding record in plant construction and cost, plant capacity factor, plant safety (as in Occupational Radiation Exposure), and in reliably fulfilling its commitments. A question for the Committee is how can such performance and capability be transferred to the U.S. nuclear program? The PIUS Reactor Program provides such an opportunity.

From Wash-1400 onwards it has been well established that for an accident in a nuclear power plant to produce non-trivial effects, it must involve a degraded (over-heated or molten) core. If guarantee against core degradation can be given, then the utility owner is protected from economic disaster, and reactor and public safety is assured. The PIUS (Process Inherent Ultimate Safety) principle, which has been pioneered by ASEA-ATOM, means providing such a guarantee without reliance on engineered safety systems that are based on the function of failure-prone mechanical or electrical components or on prompt human intervention.

Application of this principle means designing the process of heat extraction from the core so that in all foreseeable incidents, core integrity is guaranteed by the laws of gravity and thermohydraulics alone, keeping the core submerged in water at all times and avoiding a core power which exceeds the cooling capability of the submerging coolant. As the PIUS principle is realized, significant advantages are expected to accrue:

1. Add-on safety systems with their associated quality assurance requirements that now make a nuclear plant so complex and expensive will not be required.

2. A unique level of safety against malicious human intervention will be obtained.

3. The reactor owner will obtain a guarantee against possible financial ruin due to Three Mile Island-type incidents.

4. The plant, being completely operator forgiving, will allow up to a week before operator corrective action would have to be taken.

ASEA's design and development of PIUS is considered a variation of the LWR. In terms of reactor physics and kinetics, fuel service, materials and chemistry, it is a moderately-rated PWR with power densities, temperatures, flow rates, etc. well below those already demonstrated in practice. The differences in PIUS are in thermohydraulics, mechanical design and the pressure vessel. The new features, to the extent they cannot be based on existing technology, must be tested first in an engineering laboratory and then operated in a demonstration facility prior to accepting commercial orders. The totally novel feature is the pressure balancing system dependent upon stable hot/cold interfaces. The pressure balancing principle has been demonstrated at laboratory scale. A large test loop is under construction in Sweden to demonstrate the principle at temperature and pressure using a programmed heat source for simulating core power in transients. The other major development item is the steam generator, and ASEA anticipates the need for participation by a U.S. steam generator manufacturer.

A description of the PIUS design and development program is provided in Appendix A. The status of the program is as follows:

1. The conceptual design, including system descriptions, is nearing completion. Continuing plant design studies, plant operation, transient and safety analyses, and component and system development activities are underway.

2. The ASEA plant design is being reviewed by the Tennessee Valley Authority (TVA), involving Engineering, Design and Construction, Reactor Operations, and Research Organization participants.

3. The ASEA cost analysis will be reviewed by TVA during the first half of 1984.

4. The following items are not considered developmental areas:

   - Core (standard zircaloy clad UO_2 fuel at lower temperatures, flow rates and specific power than already demonstrated in industry)

   - Prestressed Concrete Pressure Vessel (Experience from eleven pressure suppression BWR containment buildings with embedded membrane leakage barrier. Vessel is on a scale with the large gas-cooled reactor in France and the UK, but simpler in design and easier to construct. Constructability and cost have been independently verified by SKANSKA, Sweden's largest construction firm)

   - Main circulation pumps (50 such pumps are in operation in ASEA-ATOM designed plants.)

5. Thermohydraulics R&D is underway

   - Basic demonstration of hot/cold interface completed in 1983 by TVA's Norris Engineering Laboratory

   - Studies being conducted at ASEA-ATOM, MIT and Royal Institute of Technology, Stockholm

   - 3MW test loop (multi-million dollar facility) under construction at ASEA-ATOM

6. Steam generator development underway, but needs a steam generator manufacturer as a major participant.

- Proposed design is of the bayonet tube type, which is also proposed for the LMFBR. Steam generation is inside the tubes with primary coolant on the shell inside.

- Comprehensive design work has been performed, but experimental verification has not commenced. Design review by a leading U.S. steam generator manufacturer is being contracted for by ASEA.

7. The development program will substantially deal with the areas of operability and maintenance, component replacement, in-service inspection, materials operating in a borated environment, various mechanical features, etc. These practical concerns are vital to commercial success for PIUS or any reactor project. Here is where the ASEA track record counts the most. It has demonstrated superiority in these areas.

ASEA-ATOM has already initiated many interactions with U.S. institutions. Last October, ASEA made presentations to the Commissioners and to the Advisory Committee on Reactor Safeguards (ACRS) of the U.S. Nuclear Regulatory Commission (NRC) and met with NRC staff, covering background information on ASEA-ATOM and its LWR program, the events leading to the PIUS program, and information on the PIUS design and development program. TVA has been cooperating with ASEA on PIUS during 1983 and continues to do so. ASEA principals have met with U.S. nuclear steam generator suppliers and have met with Oak Ridge National Laboratory (ORNL). ASEA is making arrangements for the PIUS design and development information which it is providing TVA to be further distributed to ORNL for its use in evaluating advanced reactor concepts.

ASEA participated in the January 19-20 Congressional Office of Technology Assessment (OTA) Workshop on Research and Development

Needs for Inherently Safe Reactors. At that meeting OTA requested estimates of cost and schedule for the development of the PIUS reactor in the United States under licensing and other relevant practices of the U.S. The particular interest was in development costs which would be proposed to be carried by the U.S. Government. The cost categories requested were in design, licensing, technology development and the cost of the lead plant.

In responding to this request, ASEA-ATOM has characterized a proposed possible development schedule covering each of the categories. ASEA would ask for no U.S. Government support for ASEA-ATOM in-house project activities in design and licensing. It would ask that the U.S. NRC assume its own cost in performing its own licensing activities on PIUS. In the area of technology development, ASEA-ATOM presented the main items required to bring PIUS to commercial fruition. There was some consensus among the participants in the meeting that a reasonable figure for the required level of DOE support would be $150 million, although this figure was neither suggested by nor based on estimates provided by ASEA-ATOM.

For the above-mentioned $150 million, ASEA believes the development program could include the full-scale testing of a single steam generator/recirculating pump combination using steam injection from a fossil plant boiler to simulate full power. Based on the results of this full-scale testing and all other important development activity results completed within that $150 million funding level, ASEA and the U.S. nuclear utilities and others would be able to determine the exact nature of conditions and offerings for a PIUS commercialization program. At this point it would be determined if a reactor demonstration plant were required or not. This representation by ASEA-ATOM is included in a letter (Appendix B) addressed to the Committee by Mr. Lars Halle, President of ASEA-ATOM. PIUS thus may be the least costly, shortest schedule to a commercialized inherently safe reactor program for the U.S.

ASEA-ATOM anticipates the need to develop a U.S. venture partner in the course of a PIUS development program and clearly the bulk of the U.S. funding would be spent with U.S. companies.

I hope that this information will be of assistance in your assessment of policy alternatives for development of inherently safe reactors. We understand that ASEA-ATOM is prepared to move ahead quickly with appropriate U.S. officials in creating a U.S. technology development program and plans for commercialization of PIUS in the U.S.

APPENDIX A

PIUS REACTOR PLANT

DESIGN INFORMATION
AND
DEVELOPMENT PROGRAM

ASEA-ATOM
Vasteras, Sweden

February 1984

INTRODUCTION

The purpose of the PIUS proposal is to create an intrinsically safe light water power reactor design that will:

- Simplify nuclear plant design by eliminating need for add on engineered safety systems and associated Q/A.
- Make possible economic nuclear power in smaller unit output.
- Ease siting restrictions and make possible combined heat and power schemes.
- Improve safety under more adverse conditions than considered in present licensing that may occur in e.g. third world countries.
- Alleviate public concern by reliance on laws of nature rather than failure prone equipment and human intervention.

PIUS

Design goal

As long as the core remains unharmed, no incidents in a LWR nuclear plant will give rise to releases of radioactive matter with major environmental impact.

Thus, the goal of PIUS design philosophy is protection of the core against melting or overheating under all credible circumstances.

ASEA-ATOM

PIUS

Design criteria

The core will remain unharmed when the following two criteria are met.

Criterion 1

The core shall remain submerged in water at all times.

Criterion 2

The power level of the submerged core shall not rise to a level where the cooling capability of the submerging water is exceeded. (Dryout must be avoided.)

PIUS

Design principle
The process of heat extraction from the core shall be such that fulfilment of the two design criteria will be ensured **on the basis of the laws of thermohydraulics alone** following any credible incidents, with the primary system intact, or subject to foreseeable damage.

This makes the plant:

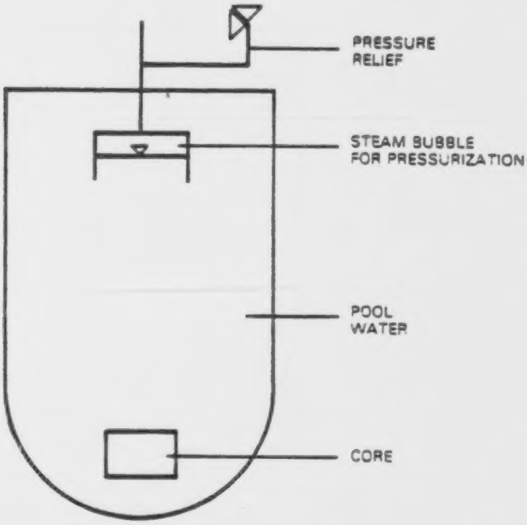
- Independent of any failure from mechanical or electrical components and systems*)
  "Murphy's law" is defeated
- Not sensitive to operator errors
- Have a high degree of immunity to destructive human intervention.

**) Note. Spring loaded pressure relief valves are used for overpressure protection.*

PIUS Design implementation

Criterion 1

Without any activated systems decay heat must be removed by evaporation of water. The water inventory must be directly available to the core — without use of pumps, valves, etc. This means a core placed near the bottom of a large pool of water (ca 1.5 m³/MWt of core power, for one week's supply).

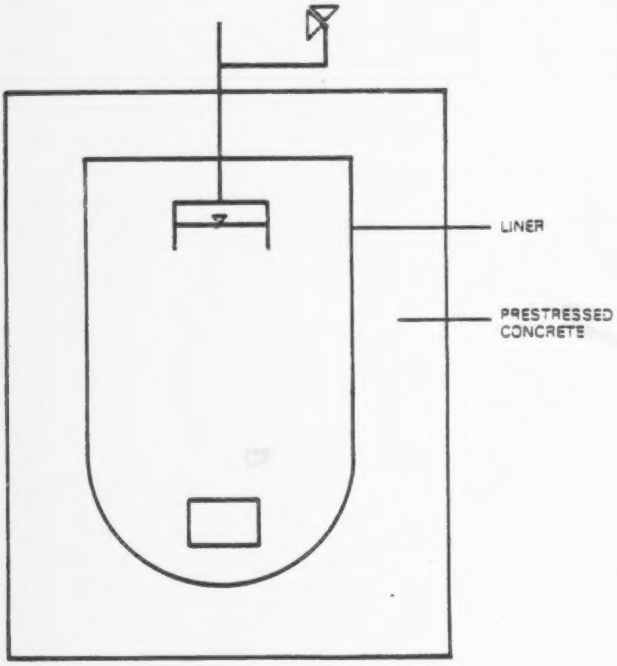

PRESSURE RELIEF
STEAM BUBBLE FOR PRESSURIZATION
POOL WATER
CORE

The pool water must contain neutron poison to exclude rapid evaporation by a critical core at power.

PIUS

Criterion 1 (cont'd)

Obviously, the pool has to be kept at full reactor pressure during plant operation. This necessitates a very large high pressure vessel (>3000 m^3 for a 1600 MWth plant). A vessel of this size can only be built in prestressed concrete.



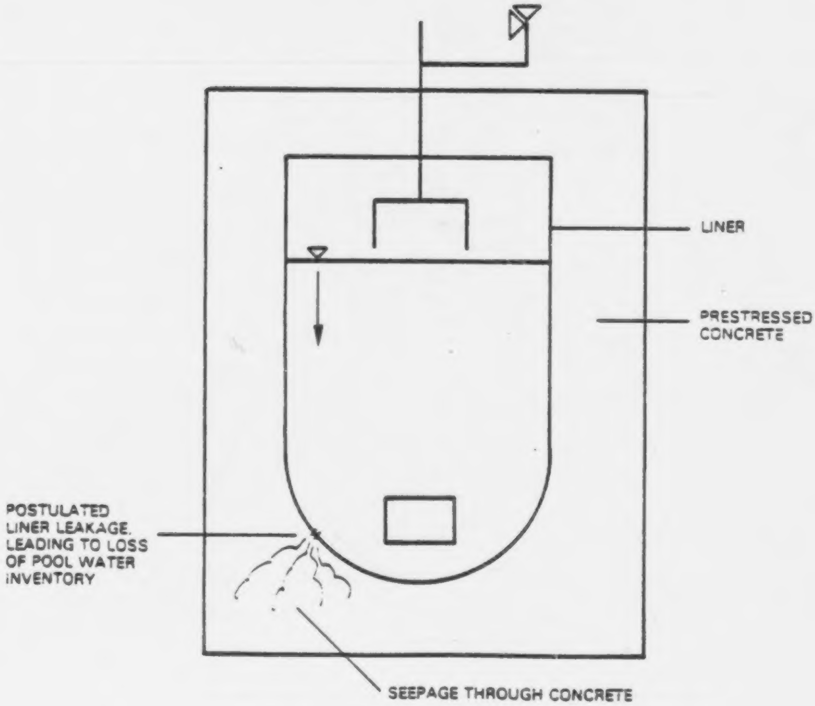
(Note: Design of the vessel is described elsewhere.)

PIUS

Criterion 1 (cont'd)

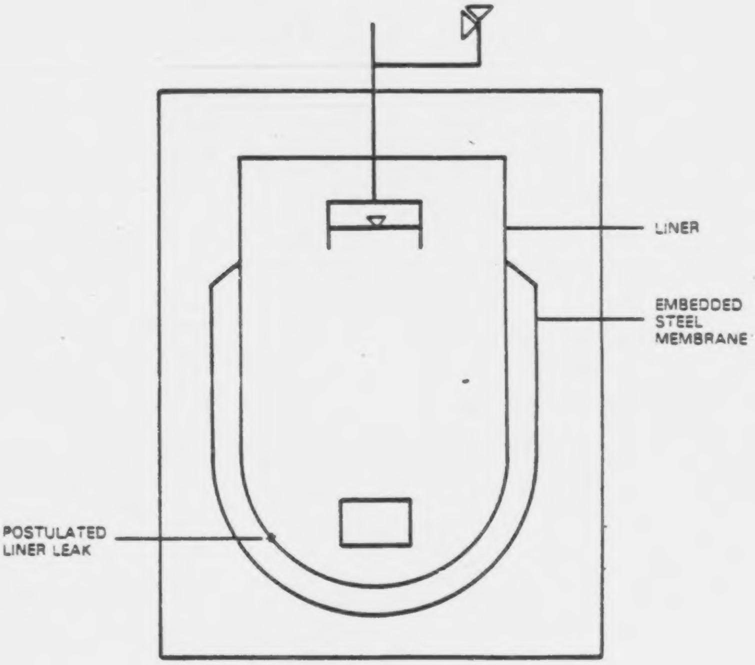
Normally, (e.g. in gas cooled reactors) leakage from a concrete vessel is assumed to be possible only at penetrations. Leakage through the vessel wall is not considered credible.

The PIUS philosophy requires a more conservative approach. It is considered conceivable that large scale leakage through the lower part of the liner and seepage through the concrete might take place, leading to significant loss of pool water inventory.


LINER
PRESTRESSED CONCRETE
POSTULATED LINER LEAKAGE, LEADING TO LOSS OF POOL WATER INVENTORY
SEEPAGE THROUGH CONCRETE

PIUS

Criterion 1 (cont'd)
To prevent such loss of pool water inventory another leaktight barrier is provided around the lower part of the vessel — an embedded steel membrane cast into the concrete. This is a feature directly adopted from all ASEA-ATOM BWR containments. Under this condition loss of water through the vessel wall can be excluded. i.e.
Criterion 1 is fulfilled.

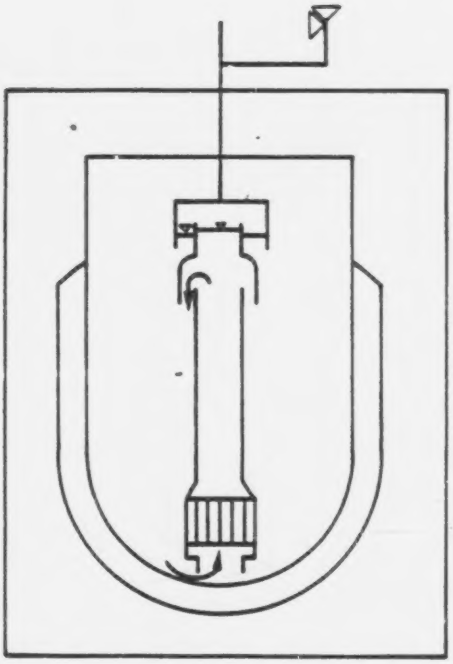

LINER
EMBEDDED STEEL MEMBRANE
POSTULATED LINER LEAK

Note. The pressure which the membrane might be exposed to, is limited to a low value by a special arrangement.

PIUS

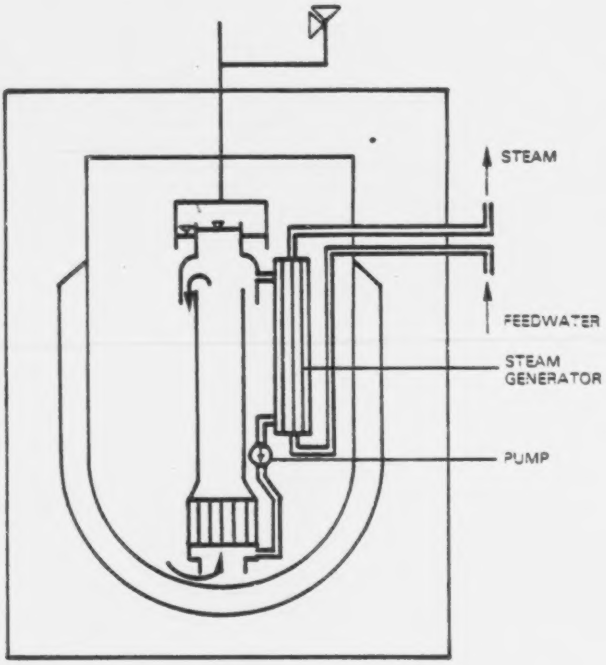
Criterion 2
A conduit structure around the core does not violate criterion 1:

The core is still cooled by naturally circulating pool water, as indicated by the arrows.



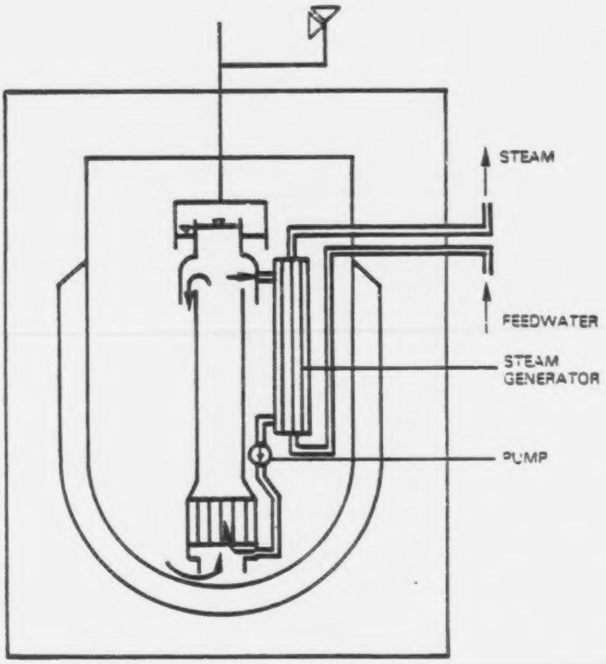
PIUS

Criterion 2 (cont'd)
Installing a pump and steam generator, as shown, will not interfere with the natural circulation flow of pool water through the core. (The pump is assumed to be idle in this figure.)


STEAM
FEEDWATER
STEAM GENERATOR
PUMP

PIUS

Criterion 2 (cont'd)
In this figure the pump is operating and transports less water than the natural circulation core flow. There will be mixing between pool and reactor circuits as shown.

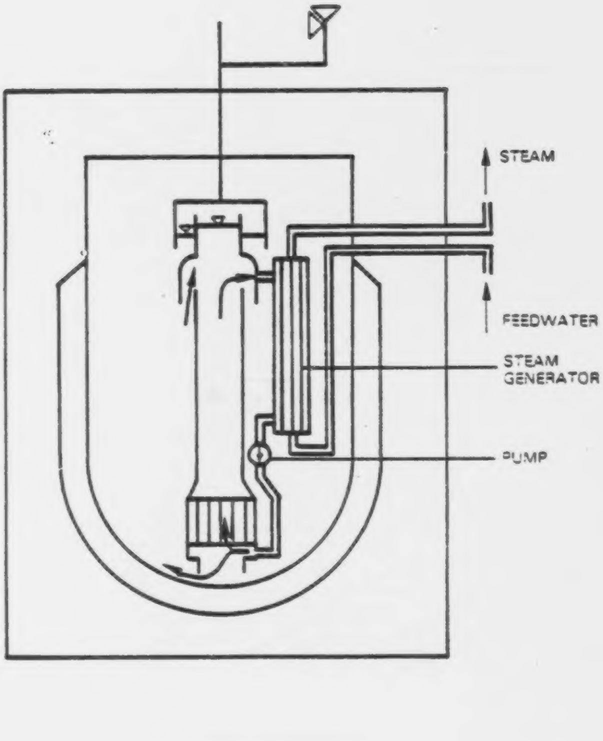

STEAM
FEEDWATER
STEAM GENERATOR
PUMP

ASEA-ATOM

PIUS

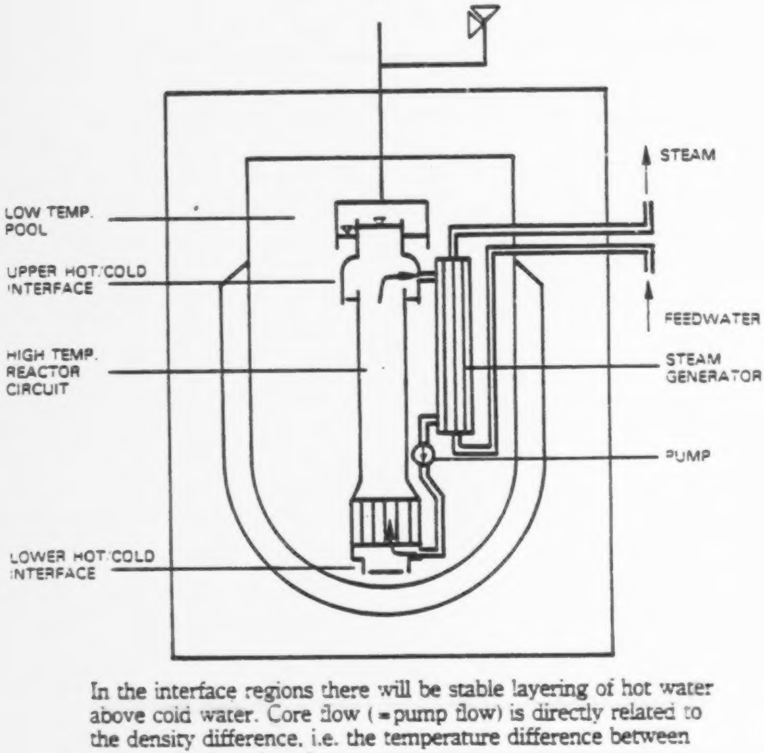
Criterion 2 (cont'd)

If the pump transports **more** water than the natural circulation core flow, there will still be mixing between pool and reactor circuit as shown.


STEAM
FEEDWATER
STEAM GENERATOR
PUMP

PIUS

Criterion 2 (cont'd)
If pump flow exactly corresponds to natural circulation core flow, there will be **no mixing** of pool and reactor circuit.


STEAM
LOW TEMP. POOL
UPPER HOT/COLD INTERFACE
FEEDWATER
HIGH TEMP. REACTOR CIRCUIT
STEAM GENERATOR
PUMP
LOWER HOT/COLD INTERFACE

In the interface regions there will be stable layering of hot water above cold water. Core flow (= pump flow) is directly related to the density difference, i.e. the temperature difference between reactor circuit and pool.

PIUS

Criterion 2 (cont'd)

Power operation:
The reactor can be brought to high power and the reactor circuit coolant to high temperature and flow rate by diluting the boron content of the coolant with pure water, while increasing pump speed along with temperature.

The lower hot/cold interface is monitored by temperature measurements, which control pump speed to keep interface at desired level.

The pump speed control range is a few per cent.

The interface region arrangement can withstand external disturbances, such as the effects of temporary grid short circuits.

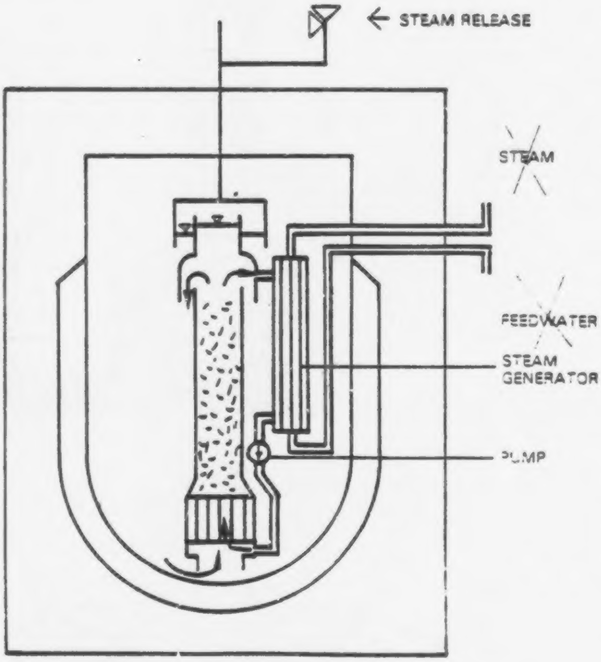
PIUS

Criterion 2 (cont'd)

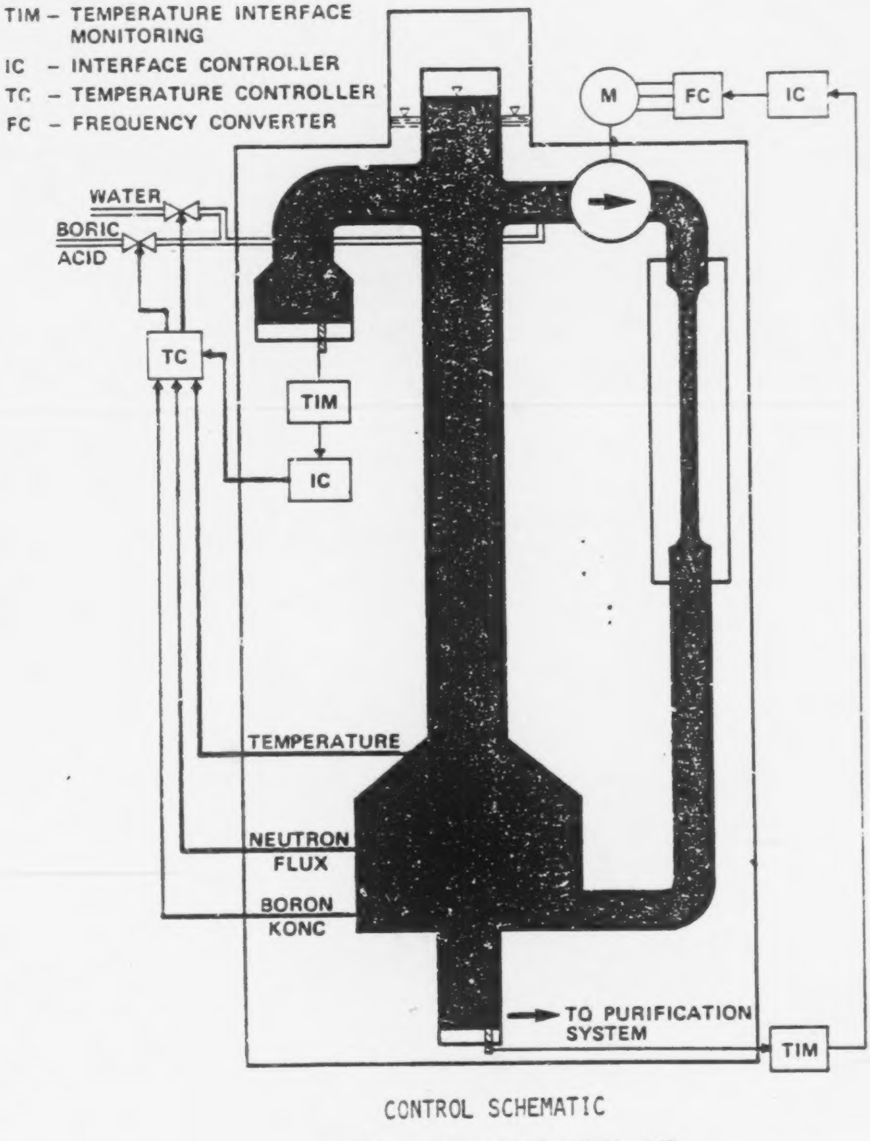
Abnormal operation — e.g. loss of heat sink (feedwater trip).

With failure of all engineered systems, the reactor circuit heats up to boiling. Steam bubbles in the riser will increase core flow beyond pump control range (due to the increased buoyancy of the riser). Pool water ingress occurs, resulting in shut down or power reduction due to neutron poisoning.

Inherent protection against destructive power is obtained.
Criterion 2 is fulfilled.



Note: This self-protective mechanism has a relatively long time constant. Separate proof is required for absence of destructive sudden reactivity insertions.


TIM – TEMPERATURE INTERFACE MONITORING
IC – INTERFACE CONTROLLER
TC – TEMPERATURE CONTROLLER
FC – FREQUENCY CONVERTER
M
FC
IC
WATER
BORIC ACID
TC
TIM
IC
TEMPERATURE
NEUTRON FLUX
BORON KONC
TO PURIFICATION SYSTEM
TIM

CONTROL SCHEMATIC

HOT/COLD INTERFACE LEVEL AND
PRIMARY SYSTEM WATER TEMPERATURE CONTROL

CORE

General:

- PWR type 16 × 16 square fuel assemblies without channels are used.
- Fuel rods have larger diameter (0.5 in) than normal PWRs, reflecting the reduced specific power (only 23 kW/kg U).
- Core height is reduced to about 6.5 ft. Combined with the reduced specific power, this decreases drastically the core pressure drop and permits the use of a pressure balance system.
- Each fuel assembly (shown) can accomodate four shut down neutron absorber rods. Such rods are expected to be a licensing requirement for a demonstration plant (but not considered necessary for later plants).
- Each fuel assembly has four rod positions for gadolinia absorbers — these are replaced each year. For longer cycles the number can be increased.

ASEA-ATOM

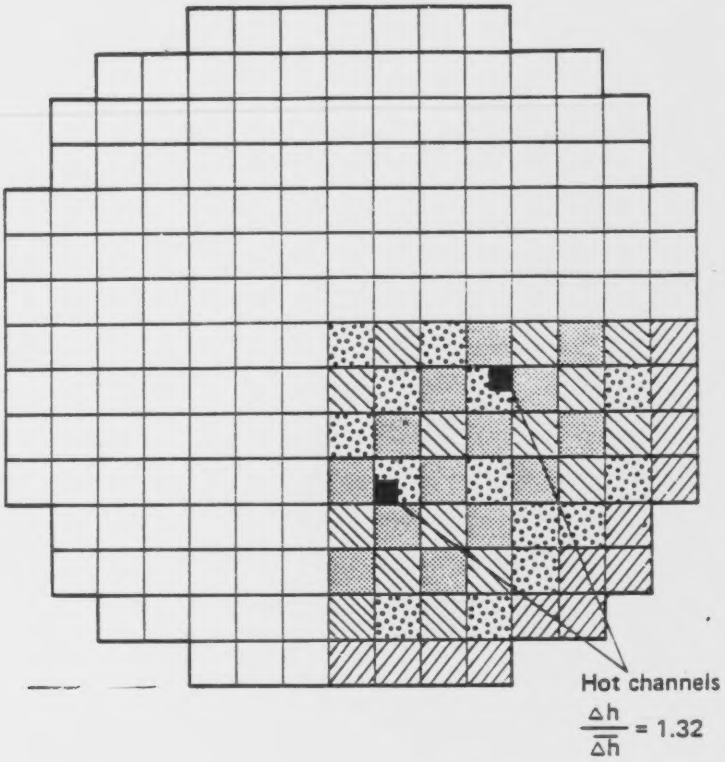
1600 MWth reactor
Core data, full power

Thermal power	MWth	1616
No of fuel assemblies		193
No of fuel rods/assembly		232
No of absorber positions/assembly		4
Fuel rod diameter	mm	12.25
Fuel rod pitch	mm	15.25
Acitve core height	m	1.97
Equivalent core diameter	m	3.84
Total amount of uranium	te	67.9
Equilibrium in-going enrichment	%	2.82
Equilibrium burn up	MWd/te	30000
Equilibrium fuel cycle length	EFPH	7500
Specific power	kW/kg U	23.7
Volumetric power density	kW/1	70.8
Mass flow	kg/s	9975
Core inlet temp	°C	263
Core outlet temp	°C	294
Pressure at core exit	MPa	9.2
Hot channel factor		< 1.4
Subcooling at hot channel outlet	°C	0
Subcooling, bulk outlet	°C	10
Core pressure drop (dynamic)	MPa	0.027

ASEA-ATOM

1600 MWth reactor

Core loading plan


Hot channels
$\frac{\Delta h}{\overline{\Delta h}} = 1.32$

193 channels

▨ Fresh fuel

⁘ One cycle old fuel

▒ Two cycles old fuel

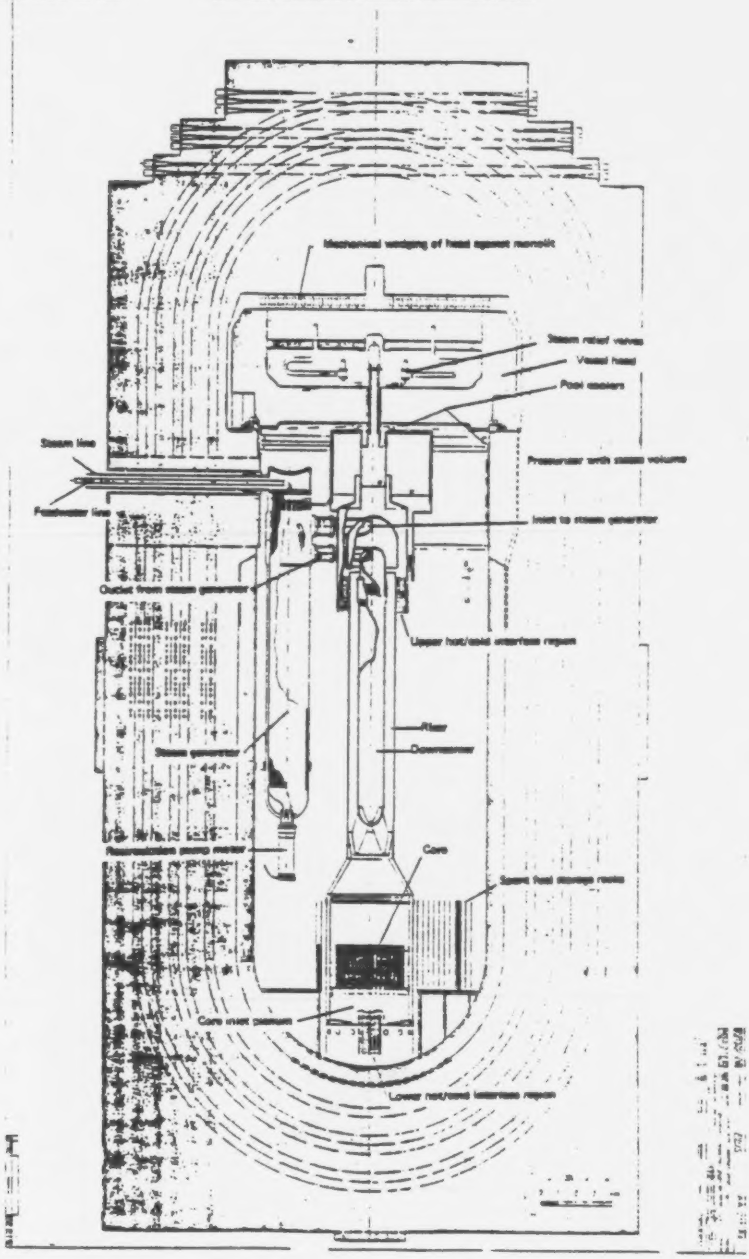
▧ Three cycles old fuel

REACTOR

General:

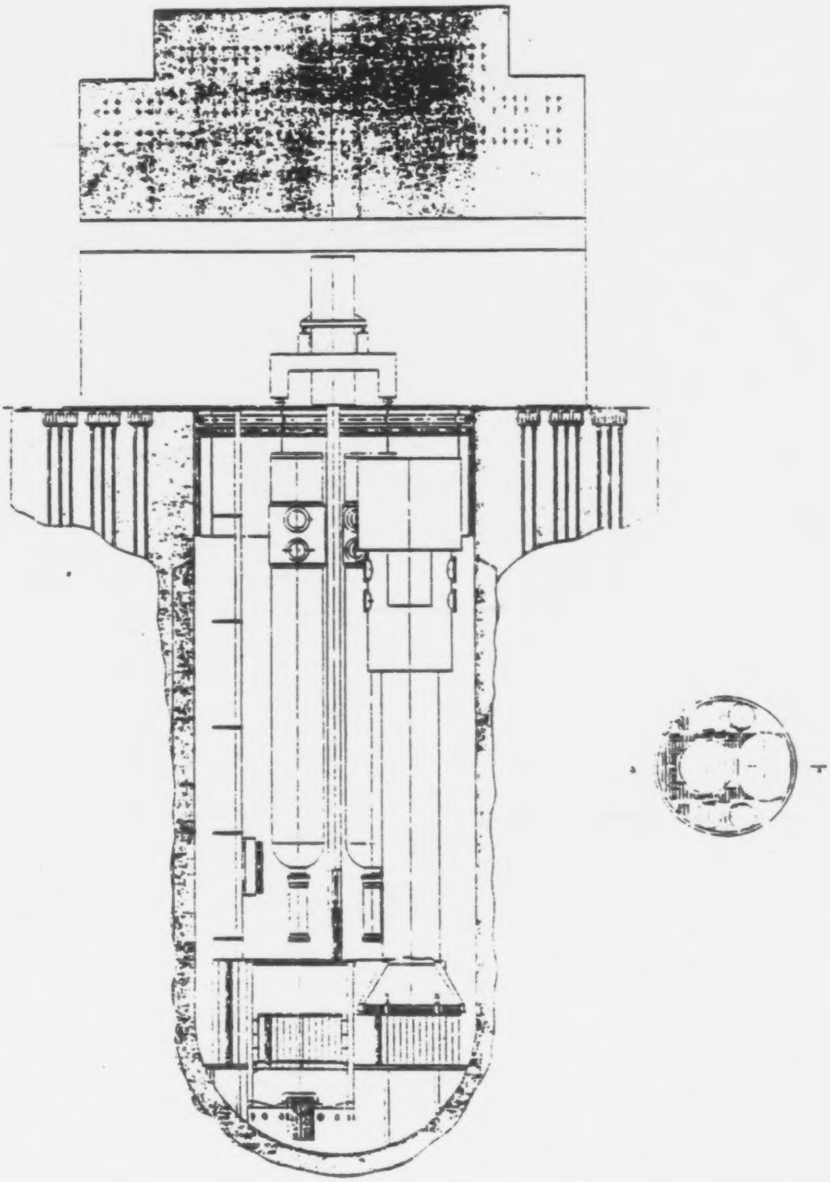
- The reactor consists of the core and a surronding steel vessel, supported on a steel structure at the bottom of the PCV cavity.
- The steel vessel has openings at both ends, and consists of an inner core vessel and an outer annulus, the latter serving as downcomer for the coolant flow recirculating to the core inlet.
- A riser/downcomer vessel is supported by the flange of the reactor vessel. Sealing is accomplished by means of C ring type seals.
- A fixture with mechanical absorber rods is placed above the core. These rods can be dropped into the guide tubes in the fuel assemblies by applying hydraulic pressure.
- These absorber rods are presumed to be required for licensing of a lead plant where PIUS transient behavior must be demonstrated. In subsequent plants they have no role and should be deleted. (These rods are not included in the remainder of the drawings.)

ASEA-ATOM CONCRETE VESSEL AND PRIMARY REACTOR SYSTEM


Mechanical wedging of head against monolith
Steam relief valves
Vessel head
Pool coolers
Steam line
Pressurizer with steam volume
Feedwater line
Inlet to steam generator
Outlet from steam generator
Upper hot/cold interface region
Riser
Downcomer
Steam generator
Recirculation pump motor
Core
Spent fuel storage racks
Core inlet plenum
Lower hot/cold interface region

ASEA-ATOM

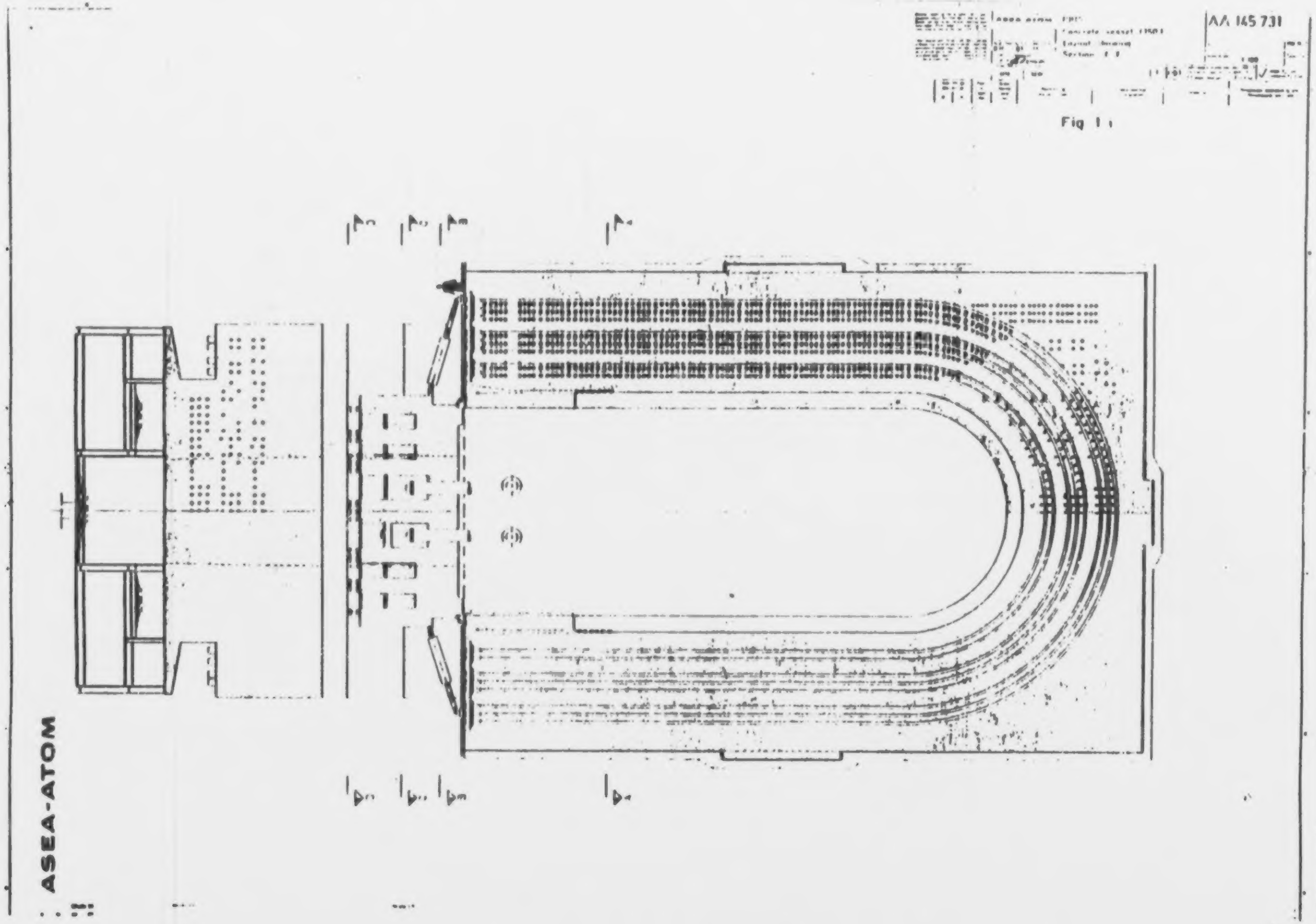
CONCRETE VESSEL CAVITY
Refuelling configuration



PRESTRESSED CONCRETE VESSEL (PCV)

General:

- Design allows full diameter access to the 43 ft diameter pool
- Vessel dimensions are large, but the design is simple in comparison with PCVs for gas cooled reactors
- Simple design provides for uniform productive and rapid construction work
- No further R & D work is necessary to verify the design


ASEA-ATOM
Concrete vessel
Layout drawing
Section
AA 145 731
Fig 1

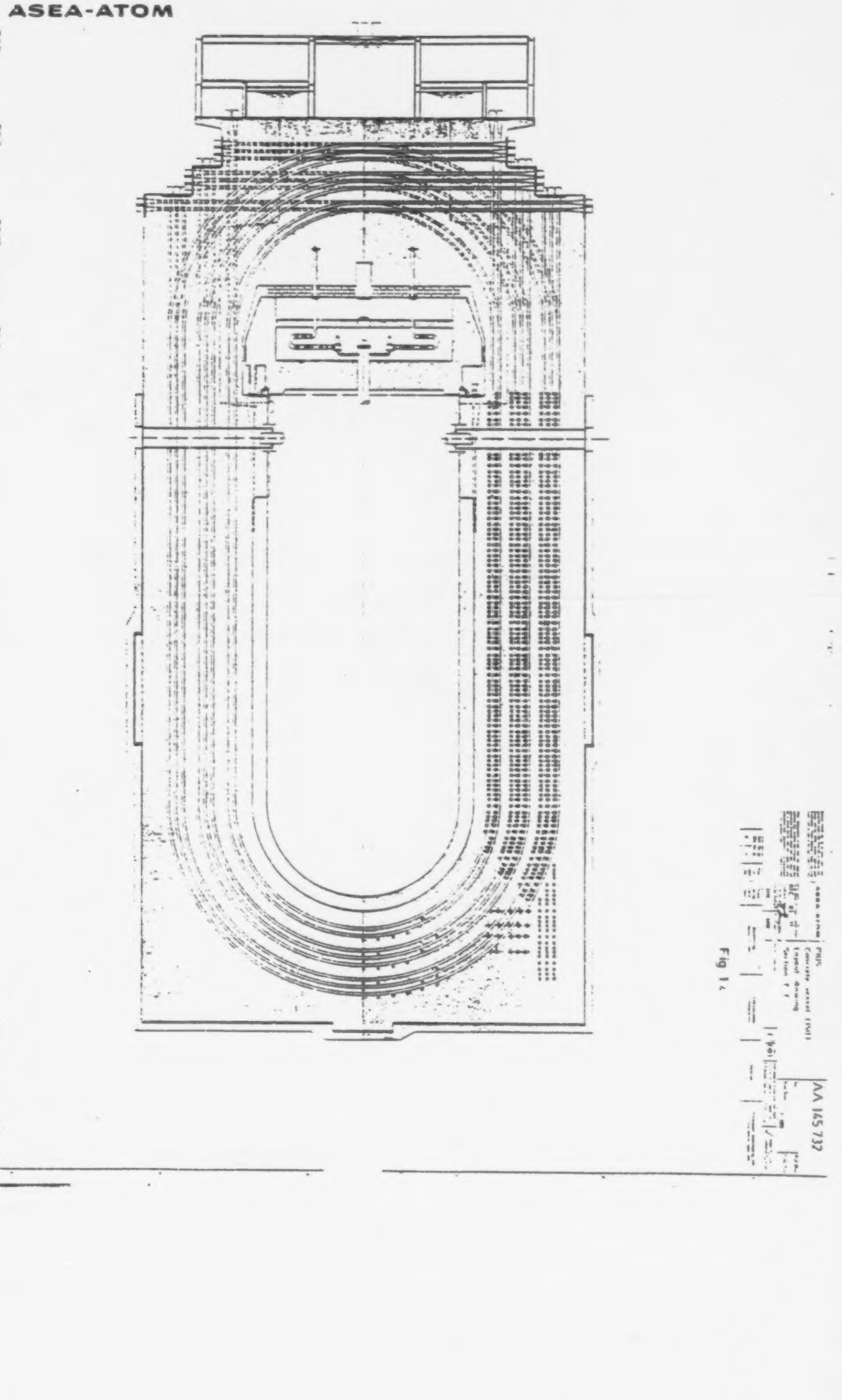

ASEA-ATOM
asea-atom
PIUS
Concrete vessel (PCV)
Layout drawing
Section 1 1
AA 165 737

Fig 1

PIUS CONCRETE VESSEL

CONCEPTUAL DESIGN STUDIES

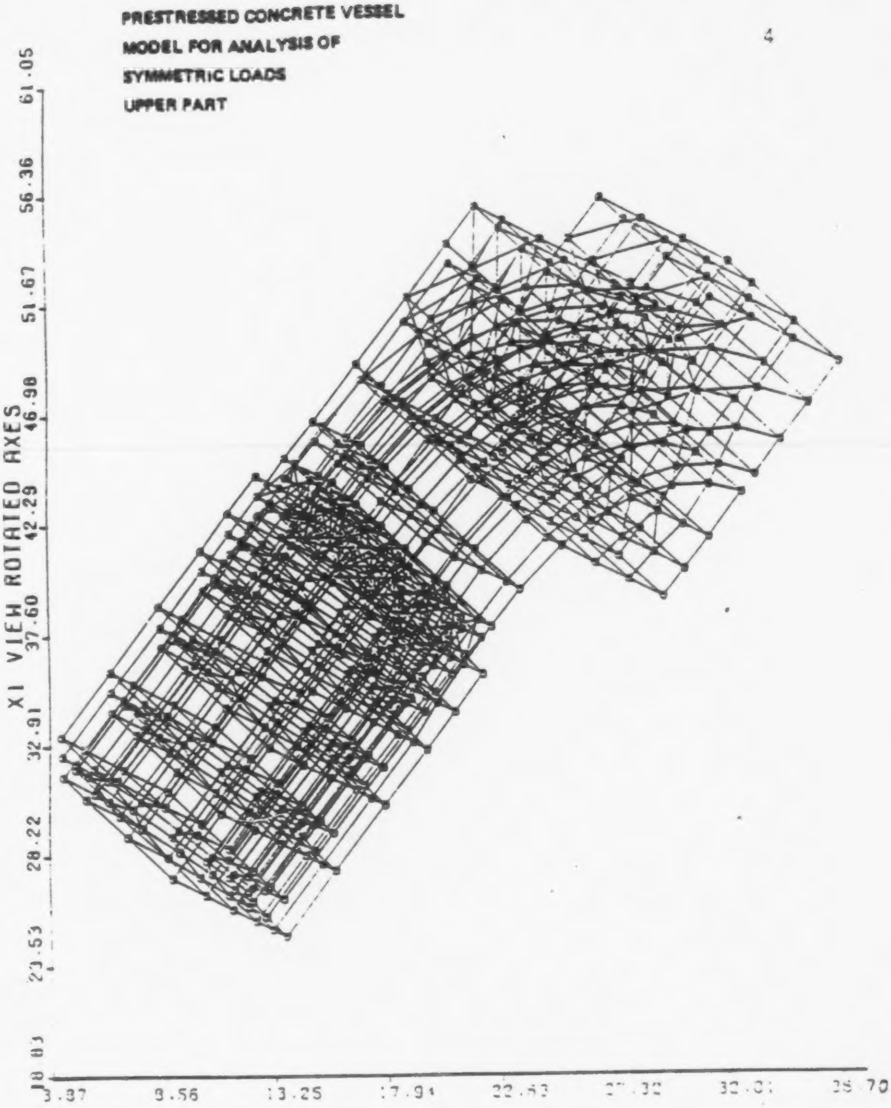
- CALCULATIONS OF STRESSES AND DEFORMATIONS DUE TO NORMAL, ABNORMAL AND FAILURE LOADS IN ACC. WITH THE ASME III, DIV. 2, CODE INCL. ULTIMATE CAPACITY CONSIDERATIONS
- CALCULATION OF SEISMIC RESPONSES OF THE VESSEL AND THE FOUNDATION
- STUDY OF CONSTRUCTION PROCEDURES AND TENTATIVE TIME SCHEDULING
- STUDY OF BARRIER TIGHTNESS (LINER, EMBEDDED MEMBRANE, CONCRETE)
- GENERAL LAYOUT STUDIES

PIUS PRESTRESSED CONCRETE VESSEL STRUCTURE

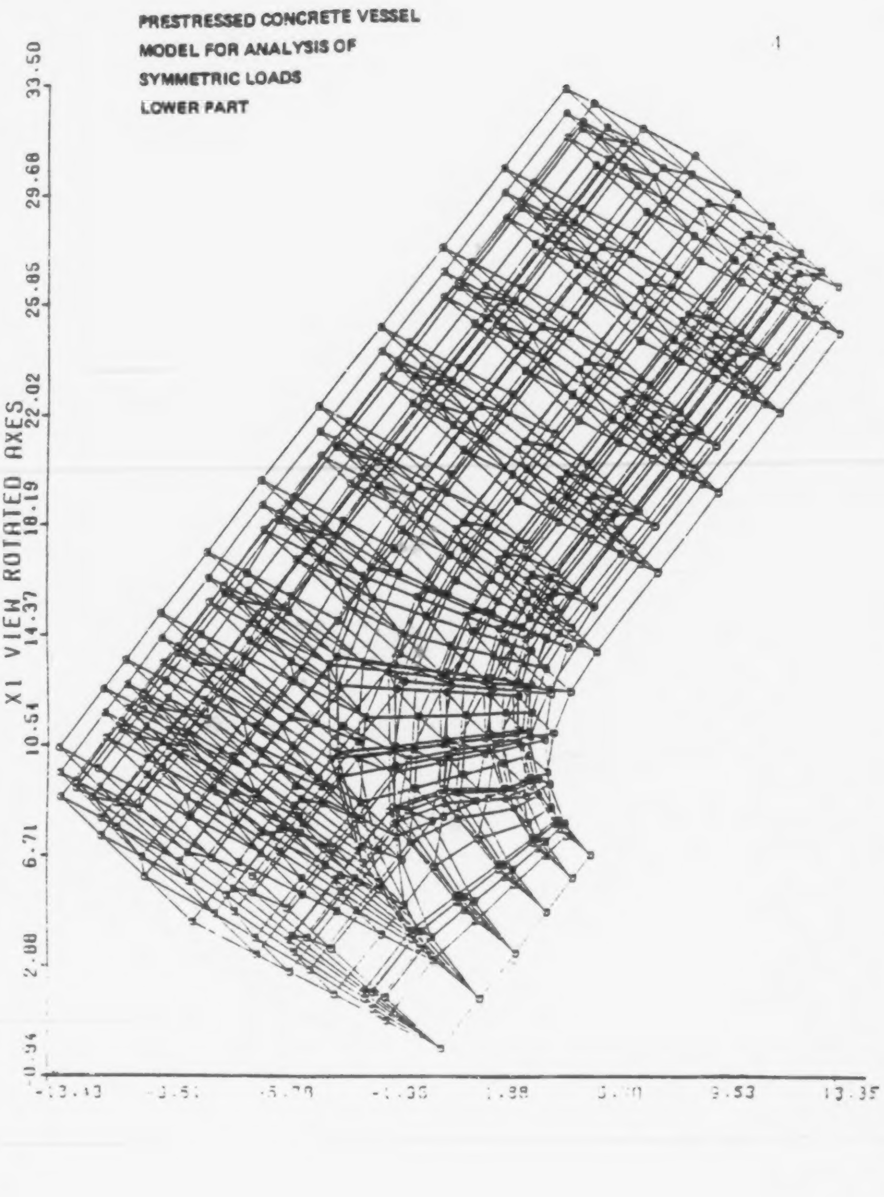
FUNDAMENTAL DESIGN RULES

- ELASTIC BEHAVIOUR UNDER NORMAL CONDITIONS
- PRESTRESSING TO A LEVEL ELIMINATING RISK OF CONCRETE CRACKING AT DESIGN PRESSURE
- ULTIMATE CAPACITY PRESSURE TWICE THE MAX. OPERATING PRESSURE (RELIEF VALVE OPENING PRESSURE)
- REDUNDANT LOAD BEARING REINFORCEMENT CAPABLE OF TAKING OVER LOADS IN CASE OF PRESTRESSING TENDON FAILURE

ASEA-ATOM


PRESTRESSED CONCRETE VESSEL
MODEL FOR ANALYSIS OF
SYMMETRIC LOADS
UPPER PART
4
XI VIEW ROTATED AXES
61.05
56.36
51.67
46.98
42.29
37.60
32.91
28.22
23.53
18.83
3.87
8.56
13.25
17.94
22.63
27.32
32.01
36.70

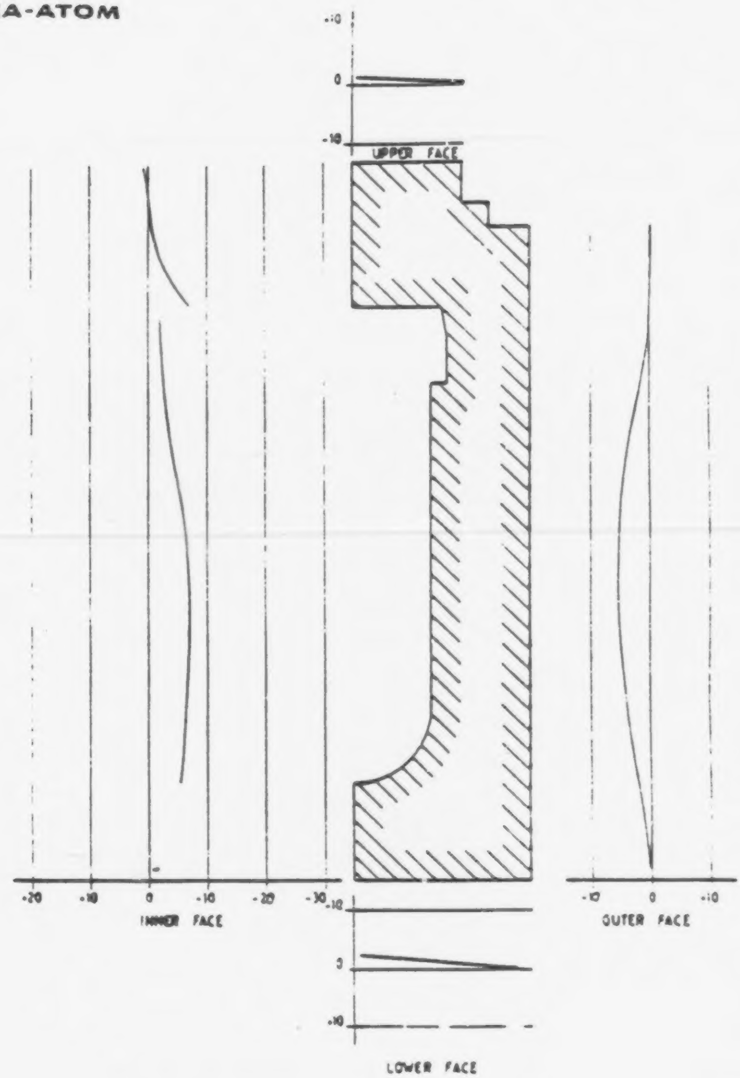
ASEA-ATOM



PRESTRESSED CONCRETE VESSEL
MODEL FOR ANALYSIS OF
SYMMETRIC LOADS
LOWER PART

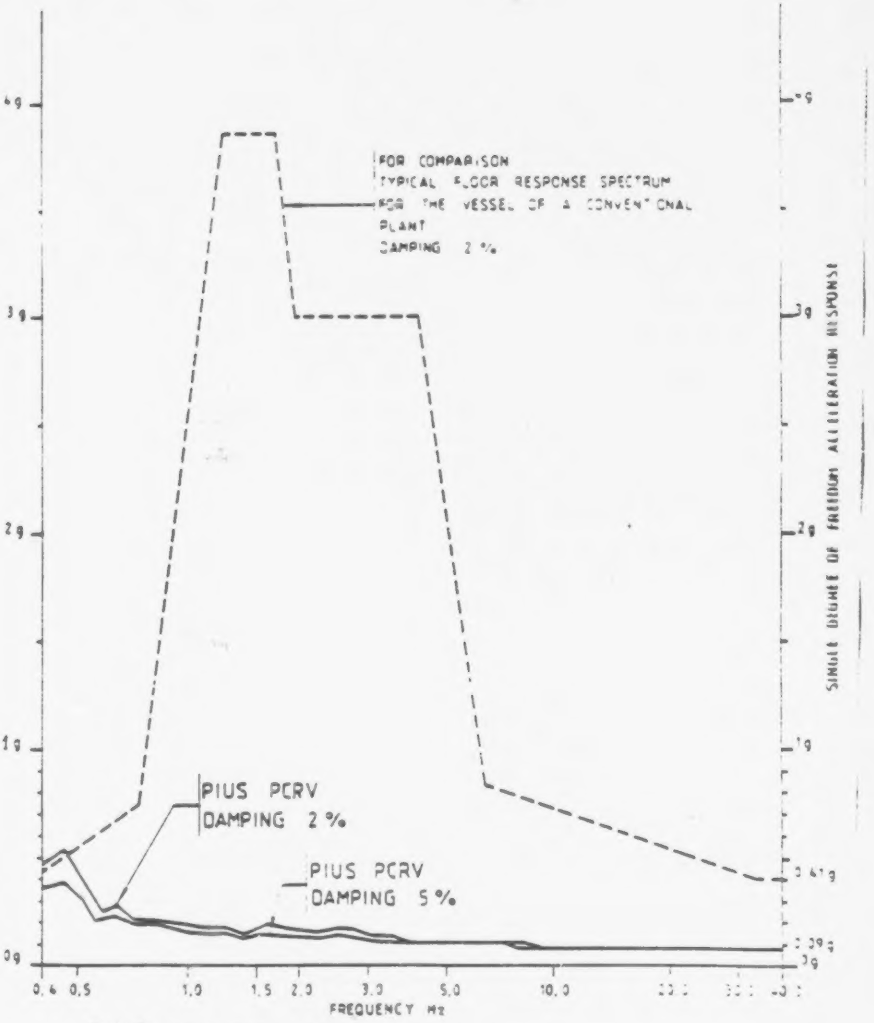
X1 VIEW ROTATED AXES
33.50
29.68
25.85
22.02
18.19
14.37
10.54
6.71
2.88
-0.94
-13.43
-9.61
-5.78
-1.96
1.88
5.70
9.53
13.35
1

ASEA-ATOM



PIUS CONCRETE VESSEL
CALCULATED CONCRETE STRESSES (MPa)
STRESS AT NORMAL OPERATING
HOOP DIRECTION

ASEA-ATOM



PIUS CONCRETE VESSEL
"FLOOR RESPONSE SPECTRA" FOR THE VESSEL AT GROUND LEVEL
SOFT SITE HORIZONTAL EXITATION 0.26 g

ASEA-ATOM

PIUS QUINTUS – CONCRETE VESSEL DESIGN DATA

1. BASIC GEOMETRICAL DATA
(Drawings AA Nos 145729-732)

Internal diameter	13.0 m
Embedded membrane diameter	15.0 m
Free height inside vessel below lid	34.5 m
Vessel bottom slab: Height below liner	8.0 m
Concrete above liner	1.0 m
Cylindrical vessel wall below lid:	
Total wall thickness	min. 7.8-8.5 m
Wall height from lower face of foundation slab to lower face of lid	43.5 m
"Circular" arc: Internal diameter	16.3 m
Wall thickness	6.8 m
Crest thickness	12.5 m
Height from lower face of lid to crest	19.0 m
Total vessel height from lower face of bottom part to arc crest	62.5 m
Removable lid: Horizontal (with "pools") dimensions	14.0 x 22.0 m
Max. height in central part	5.7 m
Min. height	2.0 m
"Reactor Service room": Free height	6.5 m
Excavation height: (6 m for the surrounding buildings + 28 m for the "pit")	6 + 28 = 34 m

REACTOR COOLANT RECIRCULATIONS PUMPS

General:

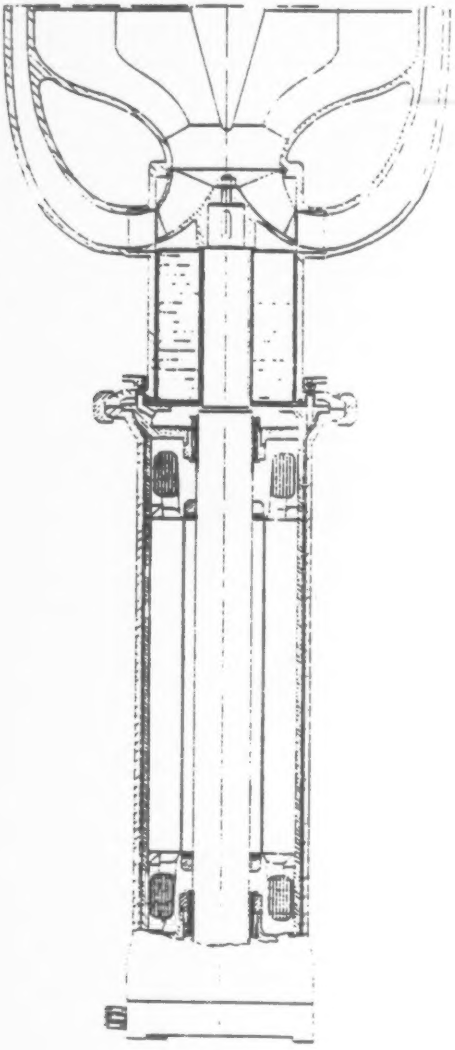
- Wet motor pumps of the kind used in all ASEA-ATOM BWRs are employed in this design. As the motor interior is filled with water, the total submersion in the pool makes little difference compared to the previous applications.

- These pumps have proved extremely reliable in ASEA-ATOM plants, and there are no mechanical seals which are subjected to the primary system pressure. For the internal pump reactors nearly one million operating hours have been logged with only one failure to date. The location inside the concrete vessel should therefore have negligible consequences for plant availability.

- The pump/motor units, together with their cables, can be removed for service by means of tools which are very similarto those that ASEA-ATOM already has in use.

- There are two qualified European manufacturers for this kind of pumps.

RECIRCULATION PUMP



ASEA-ATOM

STEAM GENERATORS

General:

- The location inside concrete vessel necessitates an unconventional design
- The accessibility for service and repair is the principal reason for choice of reentrant tube (bayonet) design. All tube to tube plate welds and orificing devices are within easy reach of service personnel (at most working through a few feet of water).
- The steam generation is "once-through" and inside the tubes. The outgoing steam is slightly superheated.
- The primary coolant flow is along the tubes on the shell side. Stabilization against vibrational wear is achieved by hydrodynamic damping in grids of short concentric tube sections.

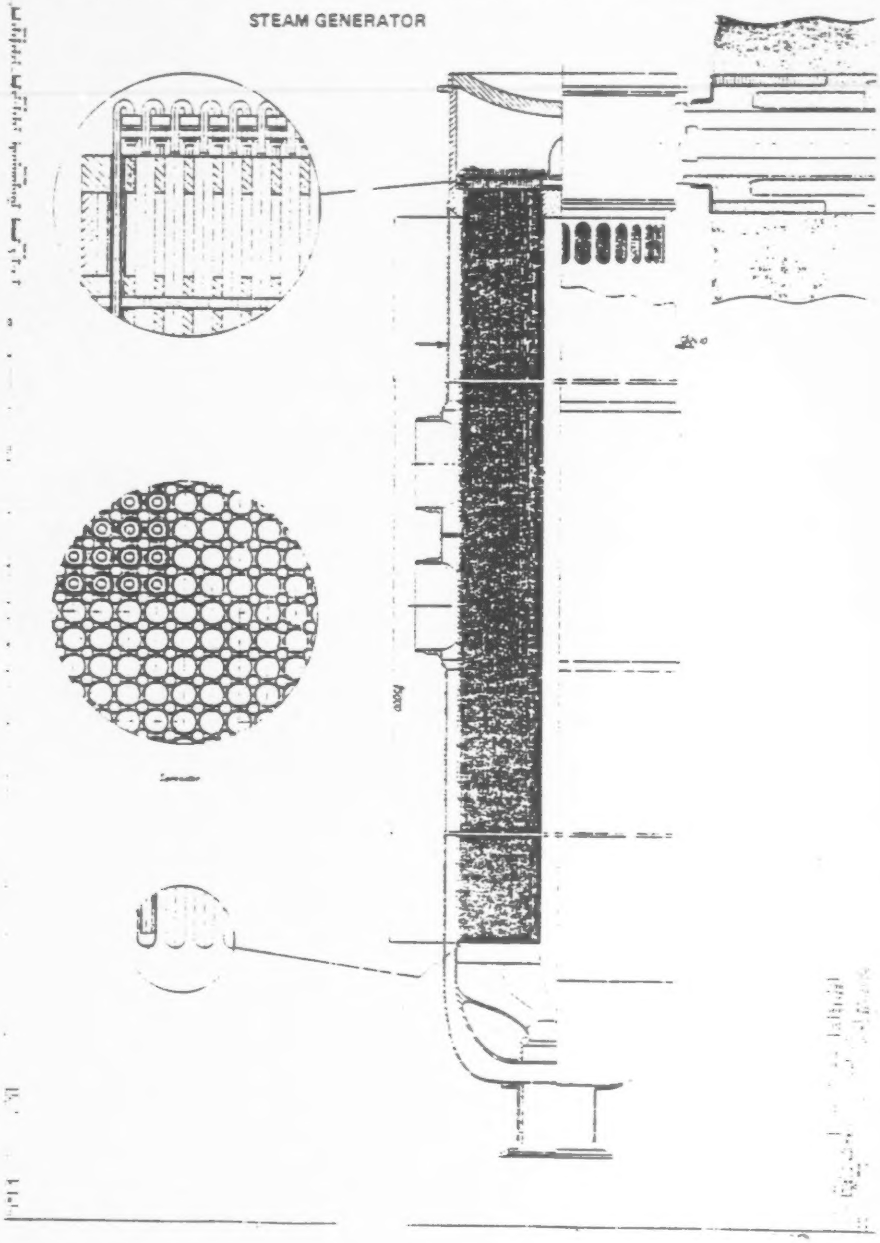
STEAM GENERATORS (cont'd)

Important differences compared to conventional PWR steam generators in terms of risk of tube failure:

- Nearly double wall thickness (0.072 in)
- Lower operating temperature
- Compressive loading of tube wall due to outer overpressure (See next figure)
- No outer stresses from tube fixtures
- No bending, flattening or cold work in fabrication
- Crevice-free secondary side

ASEA-ATOM

STEAM GENERATOR



THERMAL INSULATION

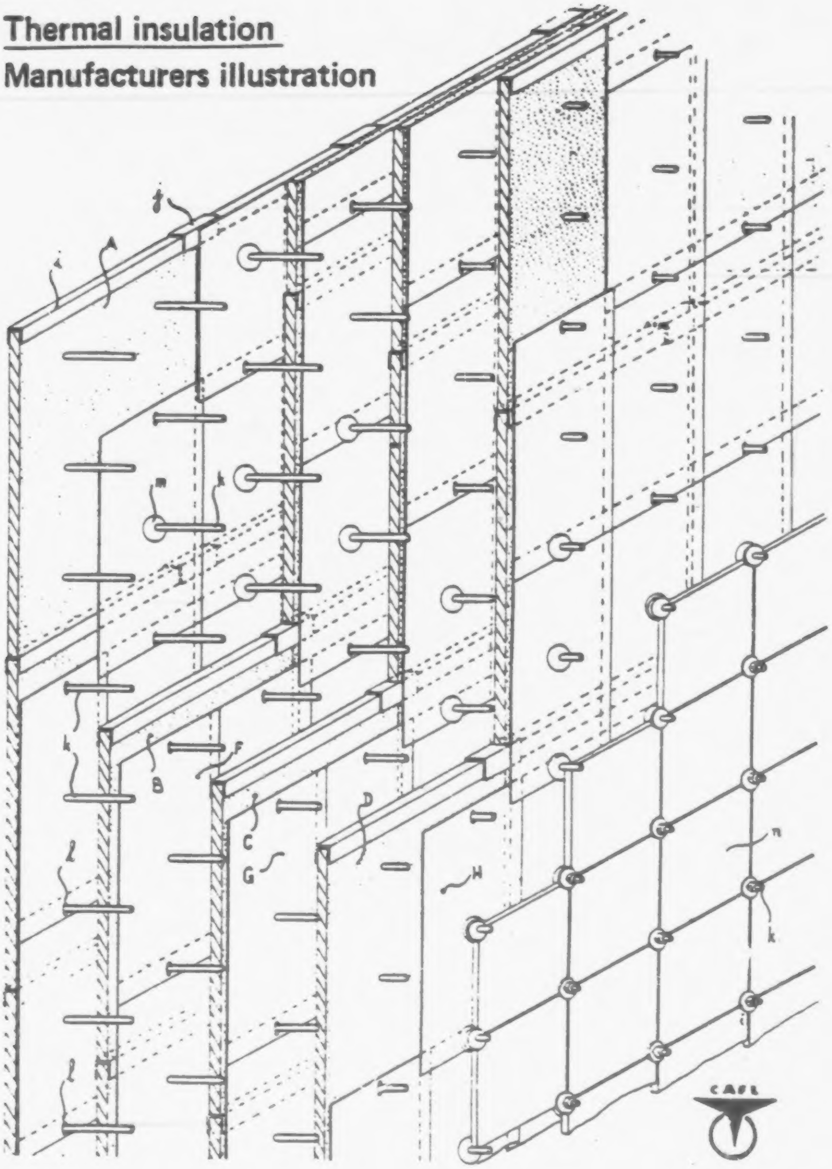
General:

- Thermal insulation is essentially achieved by stagnant water.
- This water is prevented from convecting by multiple layered stainless steel wire mesh and thin-walled sheet.
- This type of insulation is used on a large scale in French gas cooled reactors (manufactured by Creusot Loire).
- Extensive tests of the insulation system in water were carried out at Studsvik research center — in the large experimental concrete vessel — under conditions representative for this design.
- The heat loss was about 10 kW/m^2 on a vertical surface in the Studsvik tests.
- No corrosion or other life limiting problems were found in the Studsvik tests.
- ZrO_2 granules is an alternative, which is presently being tested.

ASEA-ATOM

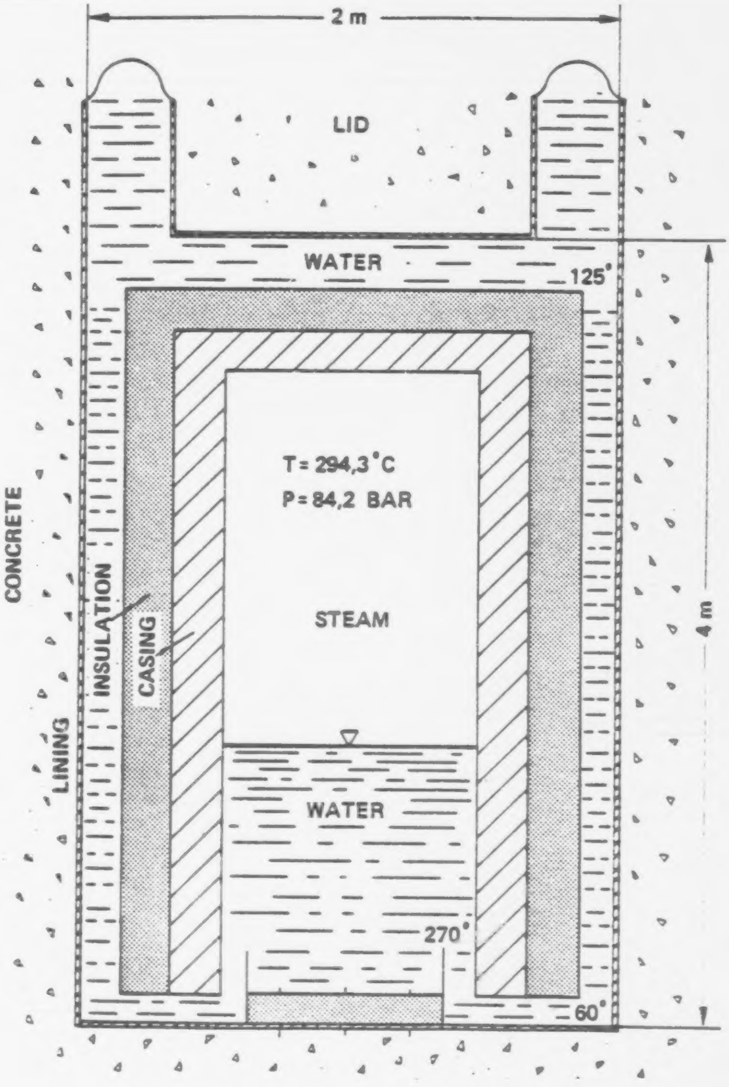
Thermal insulation

Manufacturers illustration


f
i
A
m
k
I
k
B
F
C
G
D
H
l
l
n
k
i
CAFL

ASEA-ATOM

Test of water-filled thermal insulation in the experimental concrete vessel at the Studsvik research center


2 m
LID
WATER
125°
T = 294,3 °C
P = 84,2 BAR
STEAM
WATER
270°
60°
4 m
CONCRETE
LINING
INSULATION
CASING

HOT/COLD INTERFACES

"density locks"

General:

- Layering of hot water over cold is a well known phenomenon, which is of great importance in nature and in engineering.
- Heat conductance across the interface will tend to blur the stratification, but is not important if the vertical dimensions of the "lock" are sufficient.
- Phenomena that may disturb the function of the "density locks" are stochastic local level disturbances, caused by turbulent eddies and bulk movements due to external disturbances or control system malfunction.

HOT/COLD INTERFACES

Stable stratification:

- A general measure of the stability of the stratification against turbulent disturbances is the dimensionless Richardson number:

  $R_i = g \frac{\Delta \rho \cdot L}{\rho \cdot U^2}$, where

  $\frac{\Delta \rho}{\rho}$ is the relative density difference,

  L is the height of the stratified region,

  U is a characteristic velocity, i.e. a measure of the turbulence.

The condition for stability is generally seen as being — maintain $R_i > 1$.

- In the proposed design the value of R_i is at least in the order of 25—30, probably higher, since the use of turbulence demoters can give a very low value to U.

HOT/COLD INTERFACES

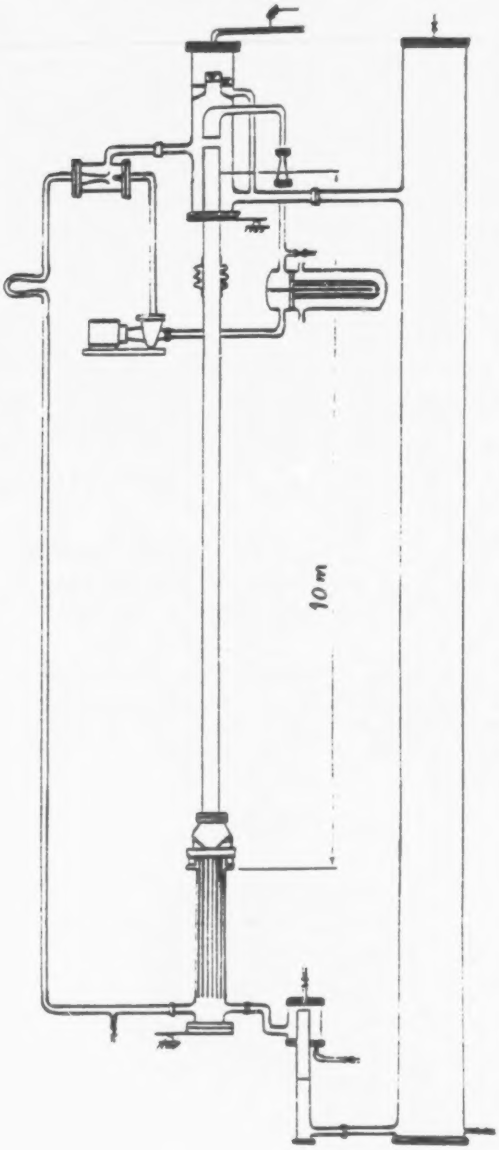
Stratification verification:

- The Tennessee Valley Authority has demonstrated stable temperature stratification using the PIUS arrangement in a small model at atmospheric pressure.
- In these tests both the density differential and the riser height are an order of magnitude smaller than in the reactor design.
- In view of these facts it is very unlikely that turbulent disturbances will constitute a problem for the design of the primary circuit of this PIUS concept.
- This conclusion is supported by practical experience from large storage tanks for hot water (heat accumulators) for district heating systems, where hot/cold stratification using low density differentials — and without special precautions to prevent turbulence — is being utilized and has presented no problems.
- In view of the novelty of the concept, an early large scale demonstration of the stratification principle is required, however. The necessary experimental effort has been committed by ASEA-ATOM and a large test loop is under construction at ASEA-ATOM's laboratory.

ASEA-ATOM

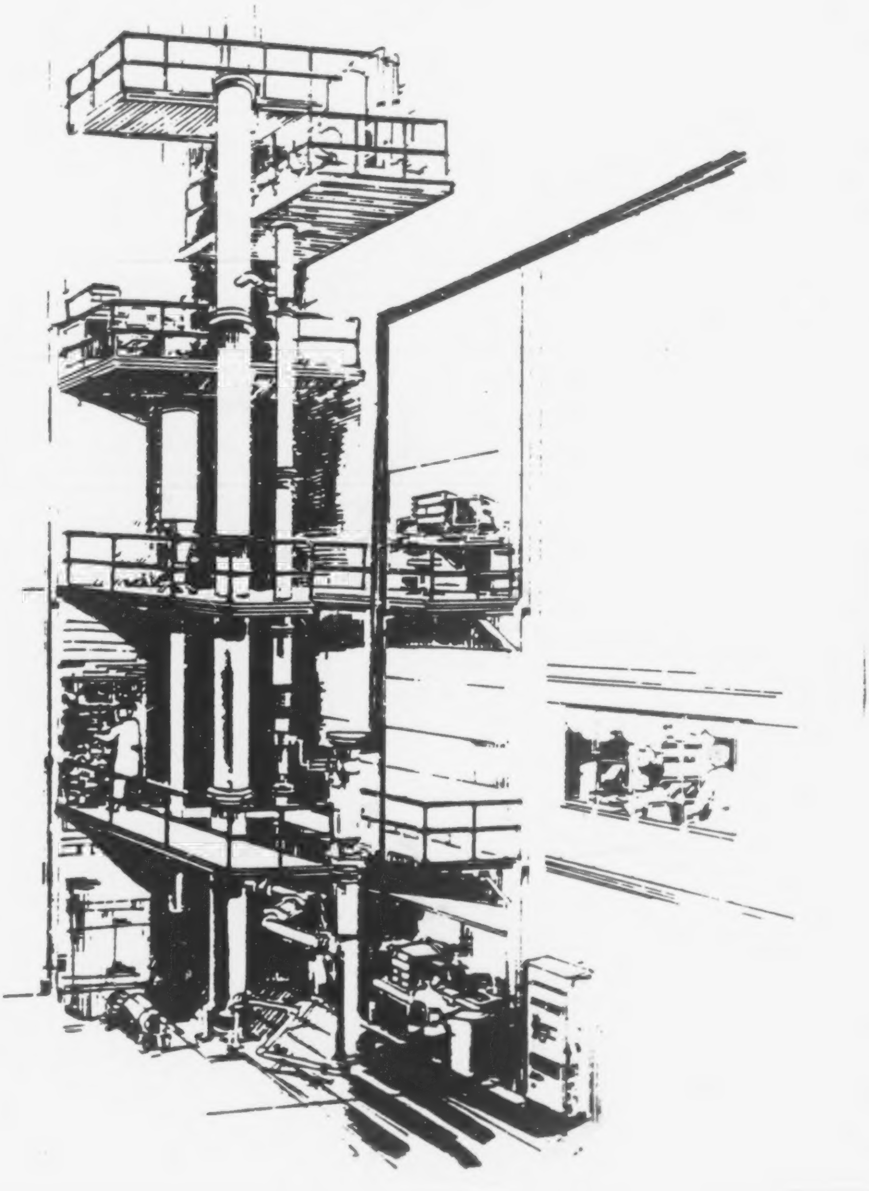
SECURE TEST LOOP

Principal arrangement

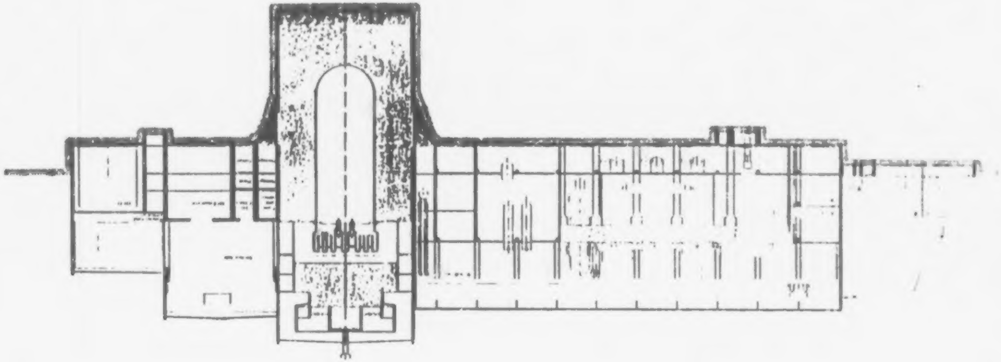


ASEA-ATOM

SECURE TEST LOOP



ASEA-ATOM



PLANT OPERATION

SUMMARY

- POWER CONTROL IS BY BORON CONTENT AND COOLANT TEMPERATURE ONLY. THERE ARE NO CONTROL RODS. BORON DILUTION MAKES POSSIBLE ≥ 2% PER MINUTE LOAD INCREASE
- BY MEANS OF GADOLINIA SHIM THE COOLANT TEMPERATURE COEFFICIENT OF REACTIVITY IS KEPT STRONGLY NEGATIVE
- THIS NEGATIVE COEFFICIENT IN COMBINATION WITH ONCE THROUGH STEAM GENERATION MAKES POSSIBLE EXCELLENT LOAD FOLLOWING PROPERTIES. FAST LOAD STEPS OF UP TO ~25% OF FULL POWER ARE POSSIBLE WITHOUT BORON DILUTION
- THE SYSTEM CAN SURVIVE SERIOUS GRID DISTURBANCES, SUCH AS SHORT CIRCUITS OF 250 MS DURATION
- PLANT START UP FROM COLD SHUTDOWN REQUIRES ABOUT SAME TIME AS FOR STANDARD LWR

PLANT MAINTENANCE

SUMMARY

- REFUELLING USES EQUIPMENT SIMILAR TO CURRENT LWRS
- SPECIAL FEATURE IS REPLACEMENT OF SHIM (GD) ABSORBERS EVERY CYCLE
- ESTIMATED TIME FOR REFUELLING IS ONLY SLIGHTLY LONGER THAN FOR EXAMPLE BWR
- SPACE FOR 15-20 YEARS FO SPENT FUEL IS AVAILABLE IN THE CONCRETE VESSEL CAVITY
- MAIN CIRCULATION PUMPS ARE REMOVED BY SPECIAL TOOLS. CURRENT PUMP OPERATING STATISTICS INDICATE THAT PUMP PROBLEMS WILL GIVE NEGLIGIBLE CONTRIBUTION TO OUTAGE. THE PWR PUMP SEAL PROBLEM DISAPPEARS.

PLANT MAINTENANCE (CONTINUED)

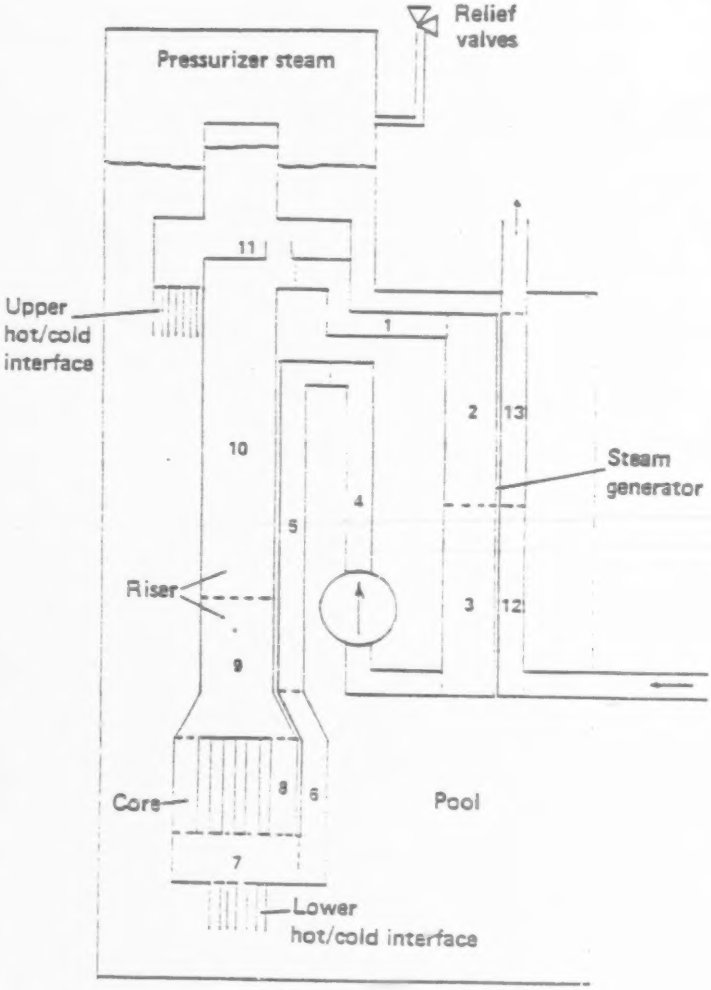
- STEAM GENERATOR SERVICING CAN BE PERFORMED WITH NEGLIGIBLE OPERATOR DOSE. REPAIR OF LEAKS OR EVEN TUBE RUPTURES CAN AWAIT CONVENIENT TIME WHILE OPERATION CONTINUES AT ~80% POWER
- STEAM GENERATORS COULD BE REPLACED IN A SHORT TIME BY CUTTING STEAM LINE WELD AND LIFTING OUT
- SUMMARIZING, LOCATION OF PRIMARY CIRCUIT INSIDE VESSEL IS NOT VIEWED AS AN IMPEDIMENT TO HIGH PLANT AVAILABILITY. INCREASED ACCESS TIME FOR REPAIR OF IN VESSEL COMPONENTS MAY WELL BE MORE THAN OFFSET BY LOWER FAILURE FREQUENCY AND LESS SAFETY RELATED INSPECTION REQUIREMENTS
- NO HEAVY COMPONENTS BECOME NEUTRON ACTIVATED. THIS GREATLY SIMPLIFIES PLANT DECOMMISSIONING. ALL RESTRICTIONS IN ACCESS TO PLANT PREMISES CAN BE LIFTED FOLLOWING DECONTAMINATION

COMPUTER SIMULATION CODES

General:

- Most transient studies have been performed by means of a computer simulation code — SLOOP — developed for this concept.
- In this code the flow path (the primary circuit and part of the secondary circuit) is described by a number of sections (nodes).
- Computer graphs shown in this section have been produced using the SLOOP code.
- Depressurization transients involving excessive void formation throughout the primary circuit have been studied by means of the GOBLIN code (an ASEA-ATOM RELAP-4 type code).

Fig. 19 Sectoring of the primary and secondary loop for the SLOOP code.


Relief valves
Pressurizer steam
11
Upper hot/cold interface
1
2
13
10
Steam generator
4
5
Riser
3
12
9
8
6
Core
Pool
7
Lower hot/cold interface

TRANSIENT BEHAVIOR

General

- In WASH-1400 (table I 4-9) are listed 18 "likely initiating events" and 5 "unlikely initiating events" to be considered for a PWR.
- Some of these are not applicable due to absence of respective components etc. It has been checked that none of the rest involves any risk of core damage **in the complete absence of intervention by the plant control systems**
- Some examples are given in the following.

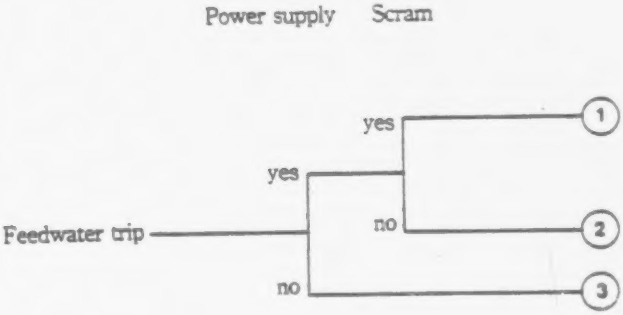
RECIRCULATION PUMPS TRIP

General:

- The pumps coast down
- The flow from the pumps to the core inlet plenum decreases
- The flow through the core initially continues unchanged
- Balance flow is taken from the pool through the lower hot/cold interface region
- The reactor is shut down by the boron ingress
- The core is cooled by natural circulation

INSTANTANEOUS FEEDWATER TRIP

Event tree



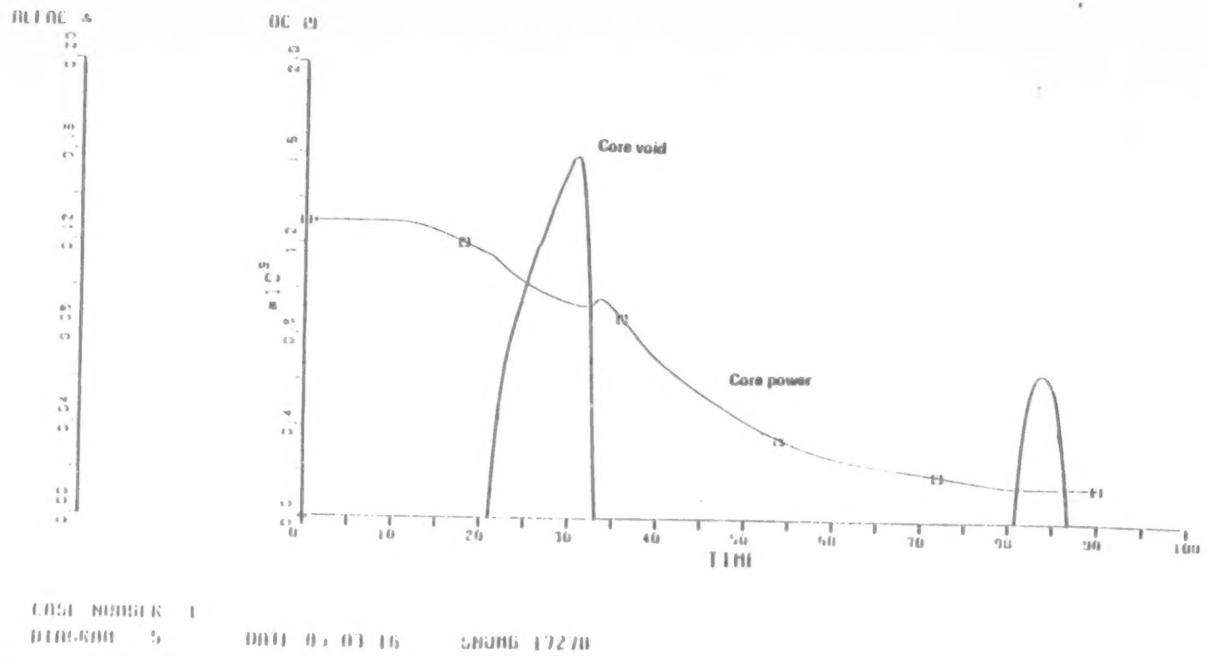
Consequences:

1) The recirculation pumps keep running. Reactor is shut down and cooled to near pool temperature. Pressurizer pressure decreases, but is re-established.

2) Recirc. pump speed goes to end of control range. Thermohydraulics of primary circuit shut down reactor without intervention of safety-related systems. (See computer graph.) Some steam is released to external condensation pool.

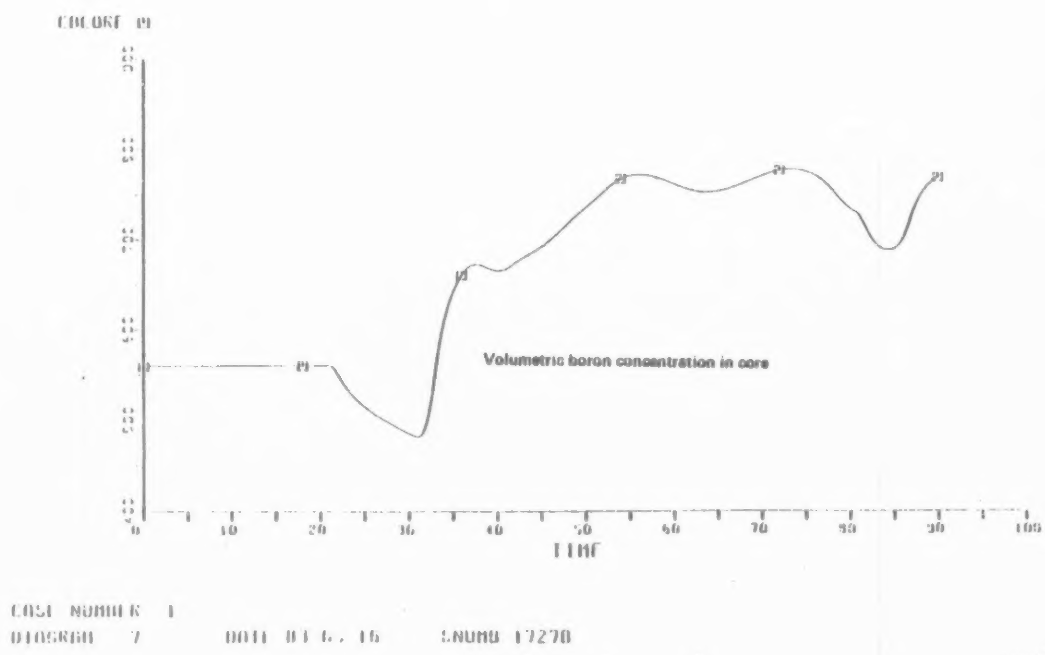
3) Recirc. pumps trip and the reactor is instantaneously shut down. Reactor pool is cooled passively to external pool.

FEEDWATER TRIP
(without safety system intervention)



ASEA-ATOM

FEEDWATER TRIP
(without safety system intervention)

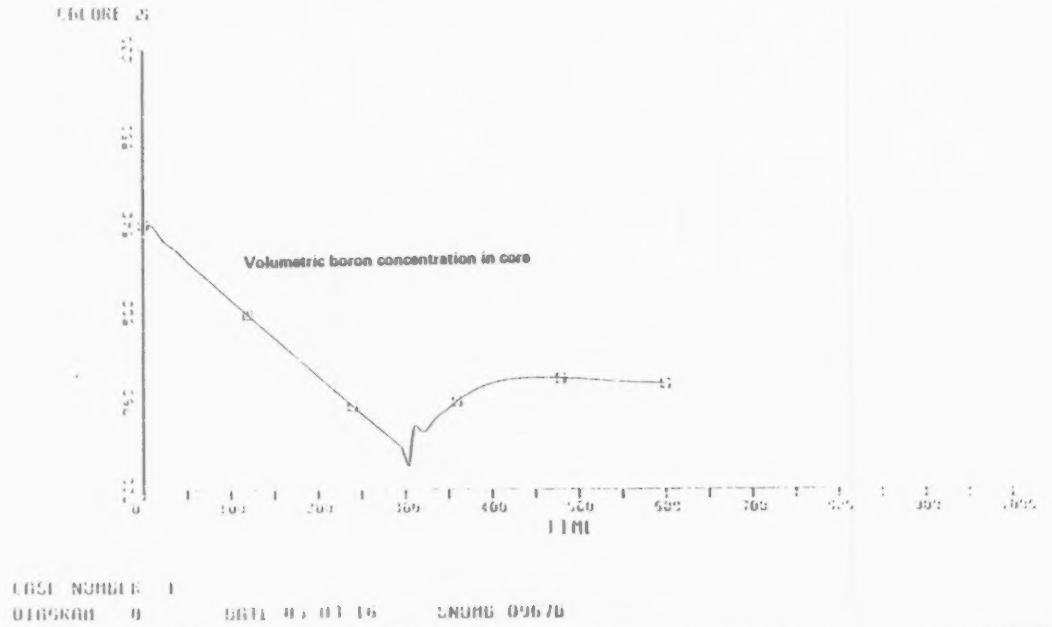


INADVERTENT REACTIVITY INSERTION

(Uncontrolled boron dilution:)

- All nuclear and thermal instrumentation is assumed to malfunction.
- Boron dilution takes place with maximum nonborated water pumping capacity used in reactivity control system.
- Recirculation pump speed goes to end of control range (5 %) to counter pool water ingress.
- The thermohydraulics of the primary circuit will limit the reactor power to level below dry out limit.

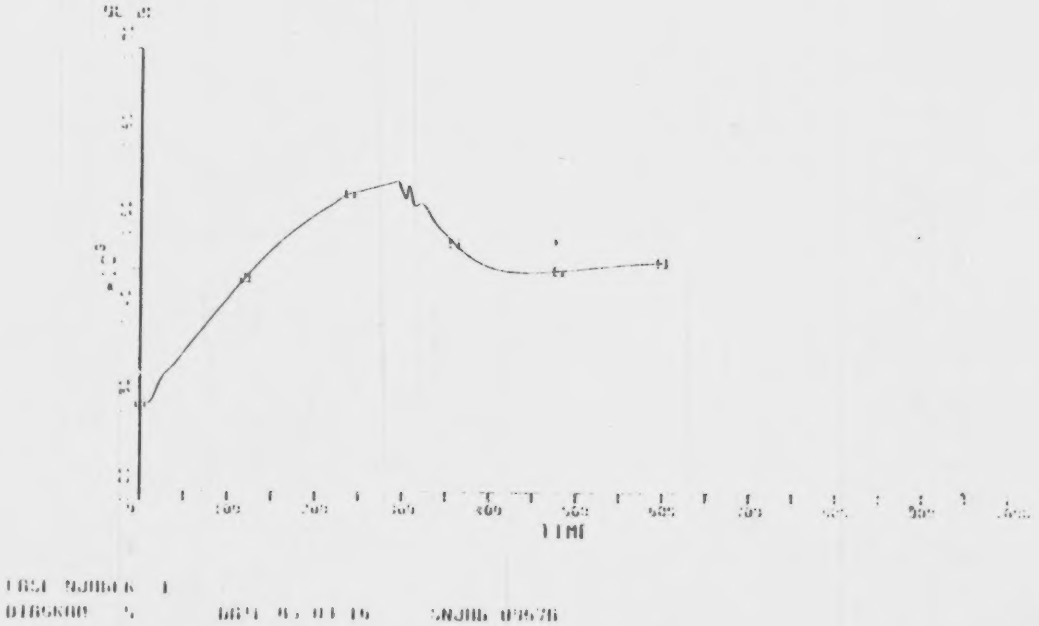
INADVERTENT REACTIVITY INSERTION
(without safety system intervention)



ASEA-ATOM

INADVERTENT REACTIVITY INSERTION
(without safety system intervention)

Reactor power



LOSS OF AUXILIARY ELECTRIC POWER

(STATION BLACK-OUT DURING DAYS)

- The recirculation pumps trip and the consequent reactor shut down and natural coolant circulation to pool occur immediately. Hot water collects in the upper part of the pool and is cooled by natural circulation to the external atmospheric pool. Three subsequent scenarios are considered.

1. Water is refilled in the external pool within appr. three days (ca 4 m³/h), e.g. by using off-site vehicles and personnel. This can go on indefinitely.

2. The plant is left alone.

   —Depressurization valves open when the atmospheric pool has boiled dry.

   —The pool water boils off through depressurization valves.

   —The core starts to be uncovered after about 20 days. Boric acid congestion of the core occurs after about one week, unless more volume is available below the core than shown in drawing.

3. The plant is left alone.

   —Depressurization valves remain closed

   —The internal pool water heats and boils off through the relief valves.

   —The core starts to become uncovered after about 12 days.

PIUS RESEARCH & DEVELOPMENT PROGRAM

PURPOSE:

To serve as a basis for decision regarding a demonstration plant

Principal activities:

1. Plant design studies
2. Plant operation, transient & safety analysis
3. Component & system development

PIUS RESEARCH & DEVELOPMENT PROGRAM cont'd

1. **Plant design studies**
    - 1.1 **Concrete vessel & internals design**
      Study of various configurations
      Detailed study of selected configuration
    - 1.2 **Supporting systems requirement analysis, system definition**
    - 1.3 **Plant layout studies**
    - 1.4 **Cost analysis**
    - 1.5 **Cost analysis critique by US Utility**

PIUS RESEARCH & DEVELOPMENT PROGRAM cont'd

2. Plant operation, transient and safety analysis

   2.1 Computer code development

   2.1.1 SLOOP 1 dedicated system simulation code.
   Developed 81-83

   2.1.2 SLOOP 6 code, advanced version under development.
   To be ready April 1984

   2.2 Analysis of all important safety related transients using the SLOOP program (complemented with a RELAP-5 type code in special cases)

   2.3 Plant operation & maintenance analysis
   Load following, start up & shut down
   Operational transients
   Maintenance time requirement assessment
   Reliability analysis

PIUS RESEARCH & DEVELOPMENT PROGRAM cont'd

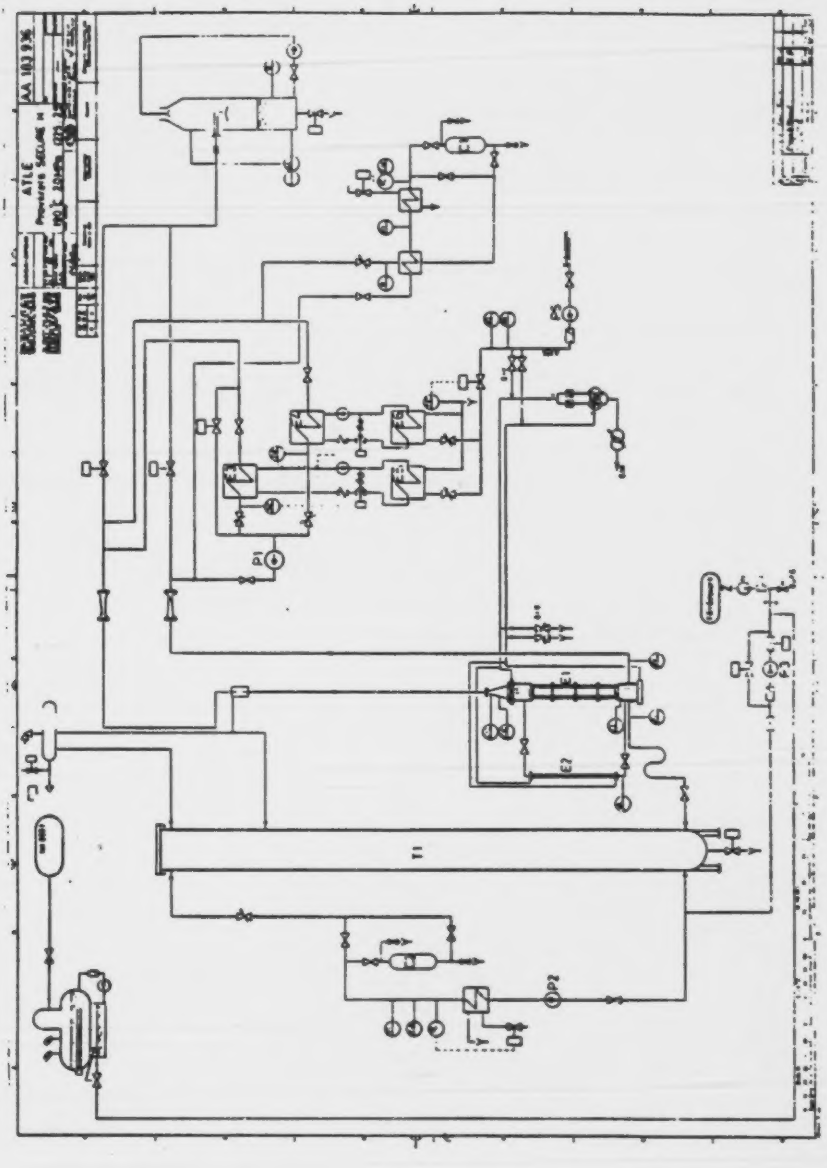
2.4 Experimental transient simulations in ATLE loop

Simulation of complete system with core, riser & downcomer, hot/cold interfaces, steam generator & main circulation pump

Core – simulated by 3 MW electric heater
Steam generator – simulated by heat exchanger
Boric acid – simulated by electrolyte

Composition, temperature and void content of coolant feeds back on core output with correct time constants by means of solid state controlled power of heater.

All important transients can be simulated


ATLE
P1
P2
E1
E2

PIUS RESEARCH & DEVELOPMENT PROGRAM cont'd

3. Component & systems development

    3.1 Development of optimum hot/cold interface region design

    3.2 Immersed steam generator development

    3.3 Wet thermal insulation development

    3.4 Flow testing in large scale model of concrete vessel cavity

    3.5 Test with mechanical shut down absorbers for demo plant (if needed for licensing)

    3.6 Full size demonstration of critical under-water handling and maintenance operations (recirculation pump remove & reinsertion, fuel handling etc)

PIUS RESEARCH & DEVELOPMENT PROGRAM cont'd

3.1 Development of optimum hot/cold interface region design

3.1.1 Demonstration of basic flow concept
Completed 1983 by TVA Hydraulics Lab

3.1.2 Systematic experimental study of fundamentals of interface behavior

Ongoing, Royal Institute of Technology Stockholm
Completed March 1984

3.1.3 Computer modelling of mixing across interface located in "honeycomb"

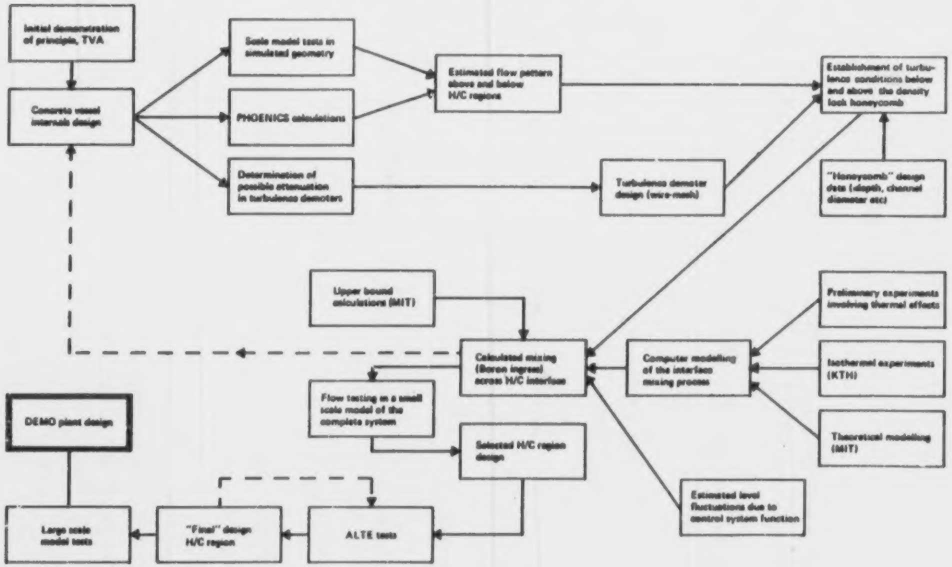
Ongoing, MIT

3.1.4 Independent upper bound calculations of mixing across interface
Planned, MIT

3.1.5 Flow testing in complete model of system
Planned, ASEA-Atom

3.1.6 Measurement of mixing across interfaces in hot operating system in 3 MW ATLE loop
Planned, loop under construction

Density lock development program logic


Initial demonstration of principle, TVA
Concrete vessel internals design
Scale model tests in simulated geometry
PHOENICS calculations
Determination of possible attenuation in turbulence demoters
Estimated flow pattern above and below H/C regions
Turbulence demoter design (wire-mesh)
Establishment of turbulence conditions below and above the density lock honeycomb
"Honeycomb" design data (depth, channel diameter etc)
Upper bound calculations (MIT)
Calculated mixing (Boron ingress) across H/C interface
Computer modelling of the interface mixing process
Preliminary experiments involving thermal effects
Isothermal experiments (KTH)
Theoretical modelling (MIT)
Estimated level fluctuations due to control system function
Flow testing in a small scale model of the complete system
Selected H/C region design
ALTE tests
"Final" design H/C region
Large scale model tests
DEMO plant design

PIUS RESEARCH & DEVELOPMENT PROGRAM cont'd

3.2 Immersed Steam Generator Development

- The PIUS design principle imposes special requirements on steam generator design. Present LWR designs cannot be directly applied. Development of a new steam generator is a major item in the PIUS R & D program.

- The design proposed by ASEA-ATOM is of the so called bayonet tube type, employed in chemical industry and proposed for LMFBR use. Steam generation is inside the tubes with primary coolant on the shell side.

- Comprehensive design work has been performed but experimental verification has not commenced. Design review by a leading US steam generator manufacturer is being contracted for.

- Most of the development work can be done at relatively low cost in a single tube experimental set up. This is because the tubes operate independently of each other between constant pressure plena.

- Thermal performance, transient behavior, corrosion and/or fauling effects of feed water impurities, inside vibration & wear etc can all be determined and design improvements verified in such a simple set up.

- Additional tests are required mainly for primary side tube support verification.

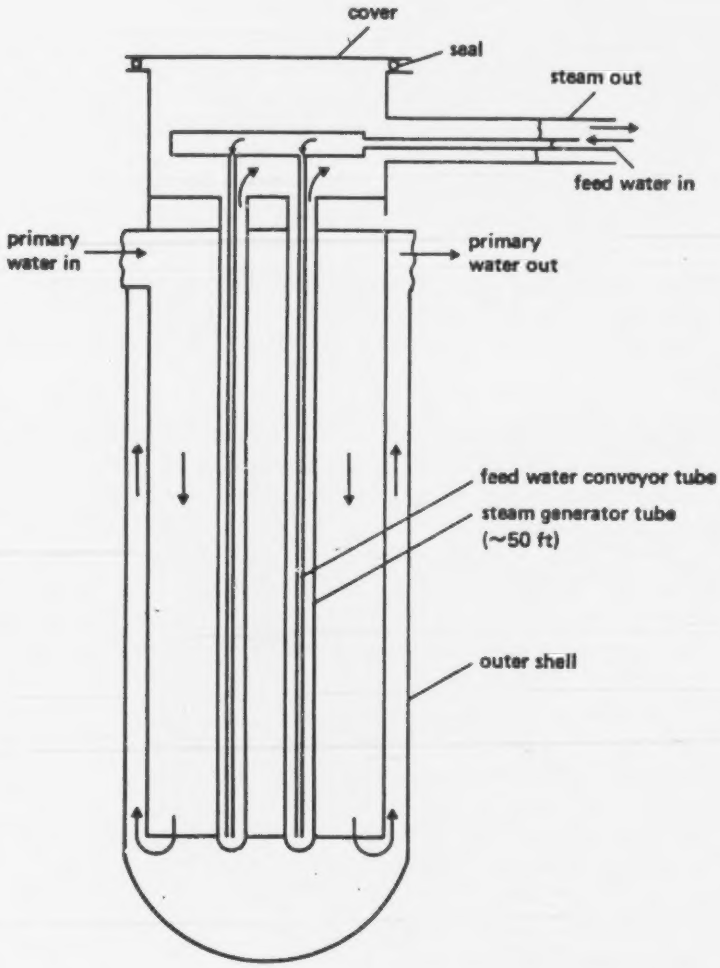
- "Proof testing" of a larger (~ 3 MW) equipment is recommendable but can be deferred to a later stage.

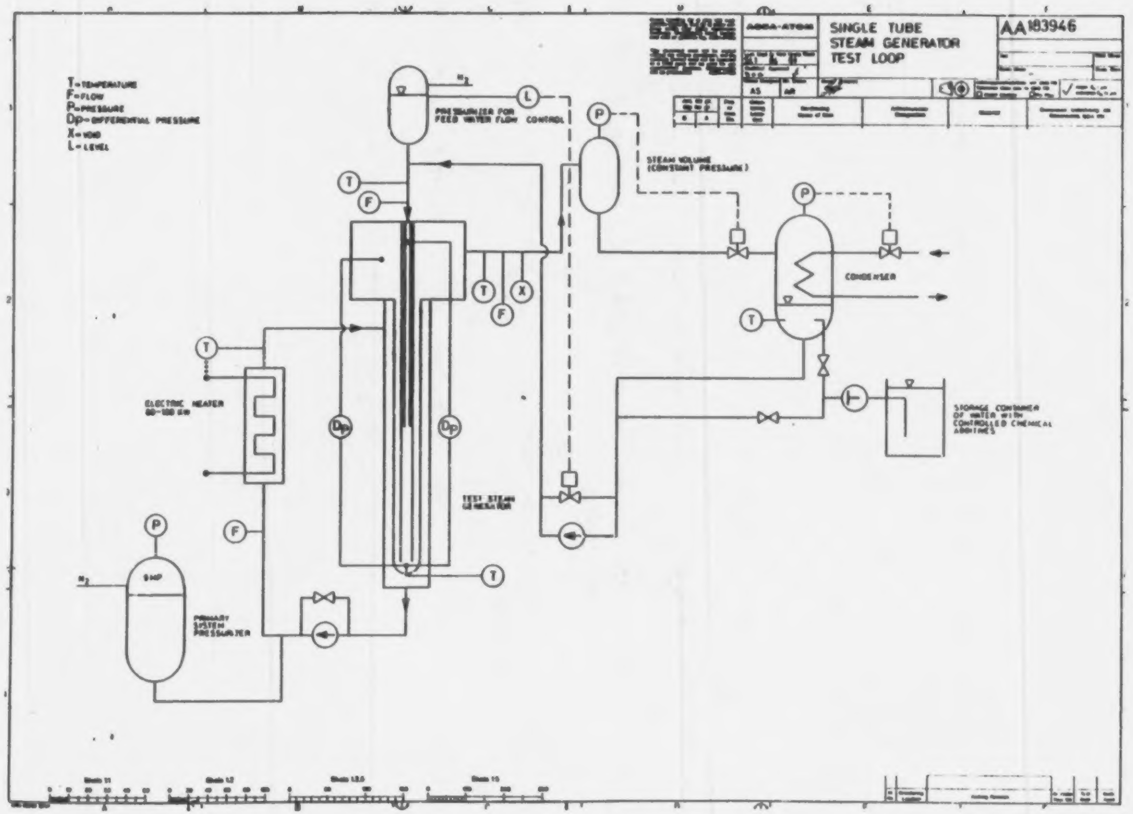
- The R & D work should preferably be handled by a steam generator manufacturer.

Fig. 1

Bayonet tube type submerged steam generator for PIUS

Design principle


cover
seal
steam out
feed water in
primary water in
primary water out
feed water conveyor tube
steam generator tube (~50 ft)
outer shell


ASEA-ATOM
SINGLE TUBE
STEAM GENERATOR
TEST LOOP
AA183946
AS
T=TEMPERATURE
F=FLOW
P=PRESSURE
Dp=DIFFERENTIAL PRESSURE
X=VOID
L=LEVEL
N_2
PRESSURIZER FOR
FEED WATER FLOW CONTROL
L
P
STEAM VOLUME
(CONSTANT PRESSURE)
T
F
X
CONDENSER
STORAGE CONTAINER
OF WATER WITH
CONTROLLED CHEMICAL
ADDITIVES
ELECTRIC HEATER
80-100 kW
Dp
TEST STEAM
GENERATOR
9 MP
PRIMARY
SYSTEM
PRESSURIZER

PIUS RESEARCH & DEVELOPMENT PROGRAM cont'd

3.3 Development of wet thermal insulation

- Insulation is wrapped around hot components in the pool. There is no insulation at the concrete vessel liner.

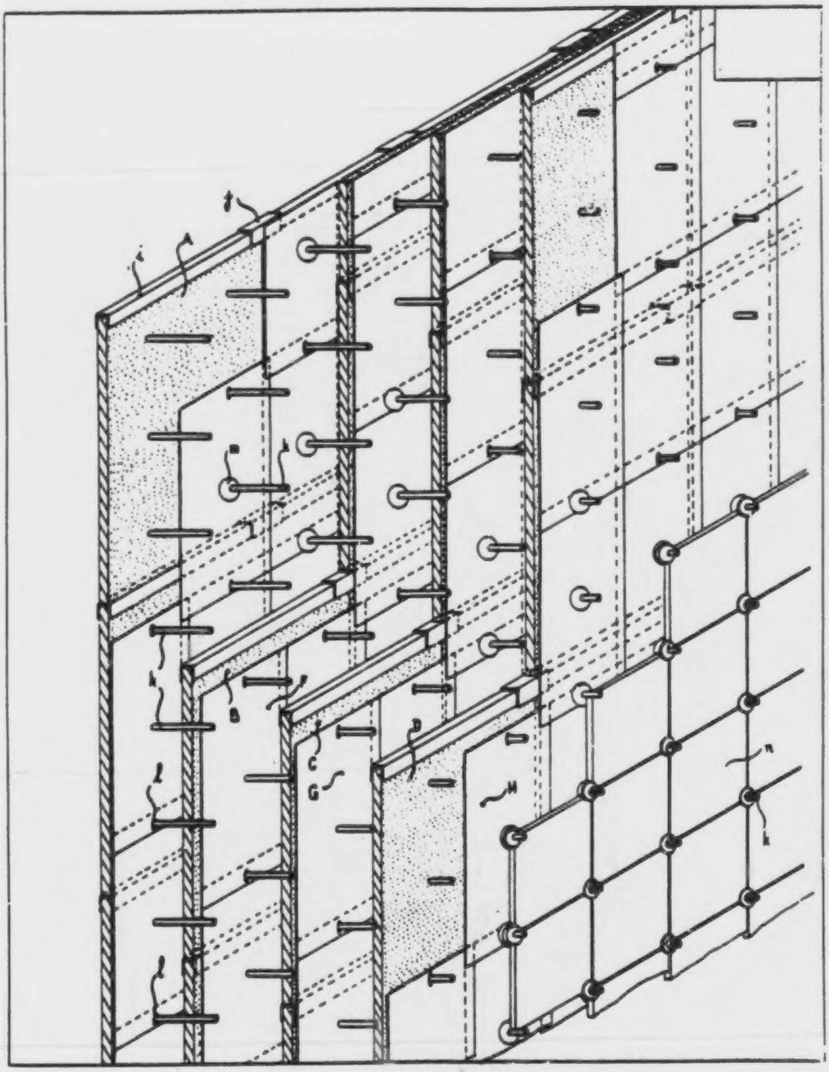
- The reference insulation is stainless steel wire mesh, interlayered with thin stainless steel sheets. It has been used in French gas cooled reactors.

- The insulation has been tested in large prestressed concrete model vessel at Studsvik in Sweden at representative temperatures (550°F steam). Heat losses were ~1 kw/sq ft

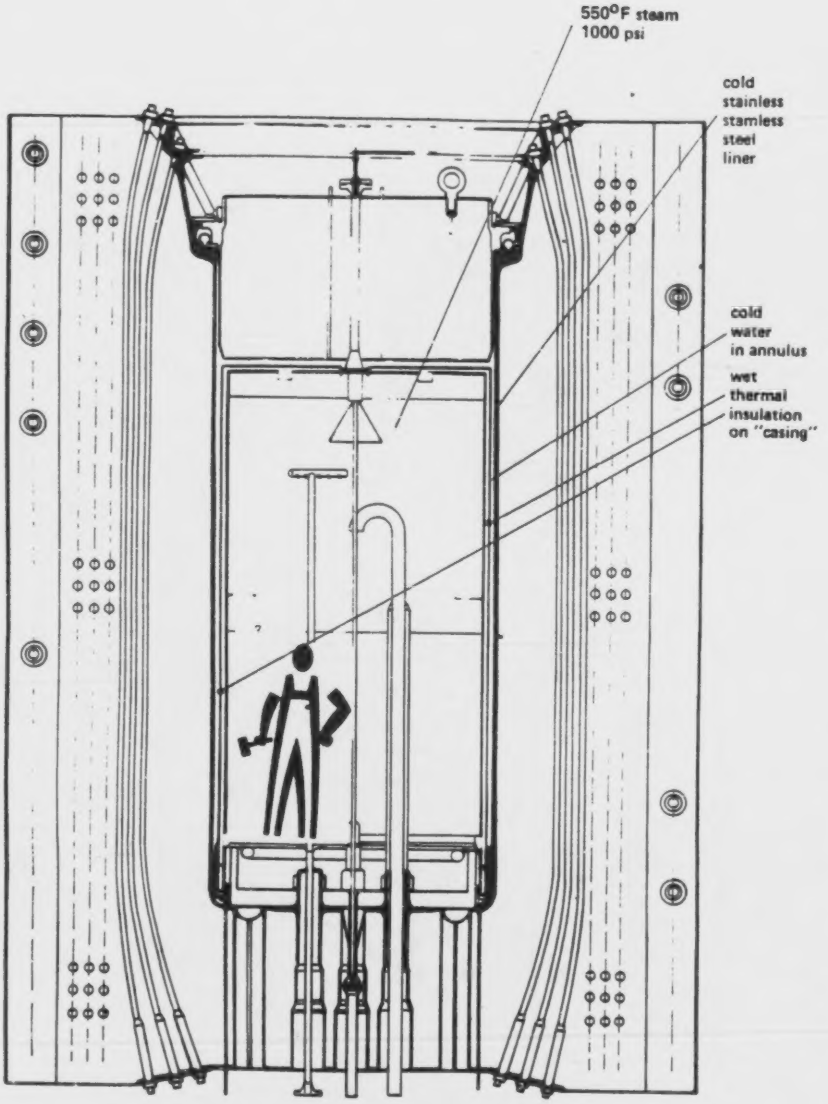
- Long term corrosion tests showing virtual absense of corrosion were also performed

- Further tests will be made later with detailed design of fixing arrangements

- Other insulation concepts are being tested at vendors laboratories


f
i
A
m
k
h
l
B
C
G
D
H
n
k

CL insulation "Metalisol"


550°F steam
1000 psi
cold
stainless
stamless
steel
liner
cold
water
in annulus
wet
thermal
insulation
on "casing"

PCRV Model vessel used for tests with wet thermal insulation

PIUS RESEARCH & DEVELOPMENT PROGRAM cont'd

4. The following are not considered developmental items

   4.1 Core

   4.2 Prestressed concrete Pressure Vessel

   4.3 Main circulation pump

4.1 Core

The core uses standard zircaloy clad UO_2 fuel at lower temperatures, flow rates and specific power than already demonstrated in the industry.

Some details of fuel assembly design have to be tested, but this can be deferred to after a demo plant committment.

4.2 Prestressed concrete pressure vessel (PCPV)

– The Design is based on

a) Extensive general experience of prestressed concrete structures

b) Design and construction experience from 11 pressure suppression BWR containment buildings with embedded membrane leakage barrier

c) 10 year multinational R & D program for high pressure PCPV involving among other a large scale (10 m high) model provided with internal thermal insulation and tested to 3000 psi.

- The vessel is as large as the largest PCPV's built for gas cooled reactors in France and the UK but much simpler in design and easier to construct
- The design of the vessel has been carried out sufficiently in detail to make sure that no major unknown difficulties need be expected that could put the basic design, constructability and order to magnitude of construction cost under normal conditions into question.
- Constructability and cost have been indepentently verified by Swedens largest construction firm.
- No further R & D is considered necessary before commencing construction of such a vessel at fixed price and construction time with full guarantees.

4.3 Main circulation pumps

- Pump type is vertical, overhung impeller, wet electrical motor suspended below pump
- 50 such main circulating pumps are in operation in ASEA–ATOM designed BWR plants
- In about 2 million operating hours one failure has occured
- There are two qualified European vendors
- The PIUS pump represents a slight extrapolation in size, but vendors can bid with full guarantees without further R &D

APPENDIX B

ASEA-ATOM

Dealt with by

For the attention of

Our Date
February 3, 1984
Your Date

Our reference

Your reference

The honourable Marilyn Lloyd,
Chairman
Subcommittee on Energy Research
and Production of the Committee
on Science and Technology
US House of Representatives
WASHINGTON, D.C.
USA

Dear Madame Chairman:

By invitation ASEA-ATOM participated in the Congressional Office of Technology Assessment workshop on research and development needs for Inherently Safe Reactors (84'), held January 19 and 20.

At that meeting OTA requested estimates of cost and schedule for the development of the PIUS reactor in the United States under licensing and other relevant practices of the U.S. The particular interest was in development costs, which would be proposed to be carried by the U.S. Government. The particular cost categories requested were in design, licensing, technology development and the cost of the lead plant.

In responding to this request, ASEA-ATOM has characterized a proposed possible development schedule, covering each of the categories.

We would ask for no U.S. Government support for ASEA-ATOM inhouse project activities in design and licensing. We would ask that the U.S. NRC assume its own cost in performing its own licensing activities on PIUS.

In the area of technology development ASEA-ATOM presented the main items required to bring PIUS to commercial fruition. There was some consensus among the participants in the meeting that a reasonable figure for the required level of DOE support would be $ 150 million although this figure was neither suggested by nor based on estimates provided by ASEA-ATOM.

Postal address
ASEA-ATOM
Box [illegible]
S-721 [illegible] VÄSTERÅS 1 Sweden

Telephone
Västerås
021 - [illegible]

Telex
[illegible]

Telegraphic address
[illegible]
Codes Western Union and Private

ASEA-ATOM

February 3, 1984

The honourable Marilyn Lloyd,
Chairman
Subcommittee on Energy Research and
Production of the Committee on
Science and Technology
US House of Representatives

Regarding the cost of a lead plant, we would like to point out that the new and unique features of the PIUS Light Water Reactor are in the areas of thermohydraulics and mechanical design. Core performance data, fuel duty and exposure conditions for the materials employed are well below what has been commercially demonstrated in the industry. The pre-stressed concrete pressure vessel is considered state-of-the-art in Sweden, but it has not been introduced significantly in the U.S.

For the above-mentioned $ 150 million, ASEA believes the development program could include the full-scale non-nuclear testing of a single steam generator re-circulating pump combination, using steam injection from a fossil plant boiler to simulate full power. Based on the results of this full-scale testing and all other important development activity results completed within that $ 150 million funding level, ASEA and the U.S. nuclear community principals would be able to determine the exact nature of conditions and offerings for a PIUS commercialization program. At this point it would be determined if a reactor demonstration plant were actually required or not.

ASEA-ATOM anticipates the need to develop a U.S. venture partner in the course of a PIUS development program, who could be either a manufacturer, an architect-engineer, a financial company, a single utility or a group of utility companies.

We hope that this information will be of assistance in your ongoing assessment of policy alternatives for development of Inherently Safe Reactors.

Sincerely yours,

AKTIEBOLAGET ASEA-ATOM

Lars Halle,
President

cc: Office of Technology Assessment
Congress of the United States
Att.: Mr Alan Crane
600 Pennsylvania Av., S.E.
Washington, D.C. 20037

Tennessee Valley Authority
Att.: Mr George Dilworth,
Assistant General Manager
400 Commerce Av.
Knoxville, TN 37902

Department of Energy
Att.: Mr Jerry Griffith
James Forrestal Bldg
1000 Independence Av., S.W
Washington D.C. 20545

Oak Ridge National
Laboratory
Att.: Mr Paul Kasten
Director of Gas Cooled
Reactor Programs
P O Box X
Oak Ridge, TN 37830

Mrs. LLOYD. Thank you very much, Mr. Young.

One of the major concerns of this committee is the recovery of the nuclear power industry to a healthy status, and it may require changes in the way the industry functions and operates. I think it's going to involve some very careful reassessments of the markets for nuclear reactors. We have to have something that we can sell, that we can put online.

From your vantage point as reactor manufacturers and designers, Dr. Arnold, Dr. Williams, can you identify specific problem areas within the nuclear industry that we really need to address and take care of before a really new reactor design can be brought to the marketplace?

Dr. ARNOLD. May I start in alphabetical order again?

Mrs. LLOYD. You may start.

Dr. ARNOLD. We are, in fact, still selling reactors through our licensees overseas, so that there is today a nuclear market. I think the domestic issue—and, of course, these are impediments overseas; there's no doubt—but the domestic issues are predictability of cost and predictability that the plant will, in fact, be licensed. I think those are the issues that we as an industry must resolve before there are orders in this country.

Mrs. LLOYD. I think you heard Dr. Brewer here this morning say, as we've said, that there won't be any new licensing legislation this year.

Dr. ARNOLD. Perhaps not, but we're not expecting any reactor orders this year, either. We believe we can identify the things that need to be done in time for it to be done.

The issue, I think, is adequately addressed in previous discussions of what form licensing reform should take. For example, one-stop licensing is still an extremely valuable goal, and we should strive to get there, even if we don't make it this year.

Mrs. LLOYD. And I share that goal with you.

Dr. ARNOLD. As far as the cost goes, I believe strongly in the availability to a utility ahead of time of a complete design and the maximum amount of factory fabrication of the thing that is put together on the plant side. We, as a company, did in fact have at one point in time some actual sales of completely built, total nuclear powerplants, our offshore platforms. We did obtain a manufacturing license for those from the Nuclear Regulatory Commission.

A variation on that in the 600-megawatt cycle size, I've already mentioned in my testimony.

Mrs. LLOYD. Thank you very much.

Mr. WILLIAMS. I think Bert commented on some of the kinds of difficulties that I think we continue to have with public perceptions, which is at least once a month or once every 2 weeks these reports on the various failures and potential failures of various components, piping and so on, all of which tie into quality, and I think constantly erode our credibility with ours and the utilities' credibility, because they don't identify anybody other than those two players in there. If we make the product and they're running it, the only people they can identify are the two of us. It's our collective credibility, I think, that's at stake in this, although obviously there are a lot of other players in there.

I think, as Howard has pointed out, the more that we can actually exercise control over it and standardize and minimize too much engineering—find something else for some of our engineers to do besides add engineering features to the nuclear reactors.

I think along the lines of public credibility, and I'll broaden my nuclear perspective a little bit and at the same time share something that Dick Walker and I experienced. Chuck Storrs commented about emergency planning and what kind of impact that can have on the public, and so on.

I think we went through emergency planning in Colorado. Dick Walker, with the Fort St. Vrain plant sitting about 40 miles north of the plant that I operated, which is the Rocky Flats nuclear production facility for weapons components, very similar to the Y-12 plant—we went through a very, very extensive kind of in parallel. He and we each had to develop our own emergency planning procedures and work with all the State components, and I think we did find that, as a result of that process, we were able to dispel a lot of the public concerns.

For example, establishing the fact that you don't have to evacuate might be an important part of that process. Unless you stand up and test it and get all of the public involved in that process, they continue to be mystified and continue to have that basic inherent fear, because nobody is really willing to talk about it. We just kind of wave our arms and tell them not to be concerned.

So I think there is a tremendous responsibility that all of us have, and I'm not sure that we legislate it or throw money at it. I think we throw our full hearts and dialog at that issue of regaining that public credibility.

Mrs. LLOYD. I appreciate that comment.

Back to responsibility of this committee, what role do you think that the Federal nuclear fission R&D program must play in bringing about a recovery of the domestic market in nuclear power? Dr. Till, would you like to comment on that as well as Dr. Arnold and Mr. Williams?

Dr. TILL. I'm not sure my comments are very useful. I know that the—that unless one finds ways of essentially exciting imaginations again in the nuclear business, even those of us who are working in it, that it's going to be very, very difficult to continue any kind of an advanced reactor program in this country.

Mrs. LLOYD. I invite any of you to comment on this.

Dr. WOLFE. I'd like to make a comment. I agree with Dr. Till and Howard Arnold on the regulatory systems. In fact, I think, despite our view that we won't get legislation through this year, I think it's necessary and, until we do, we're going to have very great difficulties in reviving any type of nuclear power in this country.

When we can—as I said before, when someone can finish a plant and not be convinced that he can build an identical plant on the same site on any reasonable schedule, on any reasonable, predictable basis, then it's clear that no utility would risk billions of dollars on that kind of an endeavor. And to make that point—I'm sorry I didn't get to you before Mr. Dager spoke, but he's been praised, and he's an ex-GE fellow, a great guy, and responsible for St. Lucie 2. Ask him why he isn't building St. Lucie 3 when Florida still needs a considerable amount of extra power.

I think a second thing—I think that's fundamental. I don't think you can build plants under the chaotic system that we have now, and I would make the point that even the plants are not apologizing for any of the lacks of—apparent lapses of quality assurance that we've heard about recently, but the thing that surprised me is that in making the decisions there was nobody who came out and said this plant wasn't safe as built or with minor modifications. The plant didn't meet some artificial specifications, and it seems to me our licensing system really has, in many cases, not much to do with safety, but more things to do about following regulations.

A second area that I think we might look at is the institutional way we develop plants. I alluded to that in my testimony.

Where there are large numbers of organizations involved at a site, and it's not always clear who is responsible for making the decisions and who is responsible really for interfacing with the regulatory authority. And one of the reasons, in my view, we have this chaotic regulatory system is they play one utility against another at times of tremendous financial stress, so that we get ratcheting frequently.

Mrs. LLOYD. Well, you know, there we go again. Licensing reform is not under the jurisdiction of this subcommittee.

Dr. WOLFE. I understand.

Mrs. LLOYD. My concern is what can we do in this committee.

Dr. WOLFE. I have one—I was going to make one more suggestion. I don't know whether it's part of this committee's——

Mrs. LLOYD. We want to know what we can do.

Dr. WOLFE. Well, let me make the suggestion, and then you can—it seems to me we have—do have a crisis of confidence, but it also seems to me that we do have technology in reactors which has demonstrated that they perform very well under the right conditions. After all, we have reactors—on average, our reactors perform better than coal plants. They produce power at half the cost of oil plants and less than coal plants, and have no environmental problems. And the best of them get built pretty well.

But I think in the future we've lost the confidence of the utility industry and the country. It seems to me one thing that the Government might consider doing is going back to the period of the late fifties and early sixties where we had demonstration projects, and I think that these—it would grieve me if we had boxed ourselves in, and your committee was so boxed in that you had to have a demonstration project for a new plant that was far out, but could not have a demonstration project for more conventional plants that we know how to build, but which would be aimed at showing that we could overcome the institutional problems that I think are holding back nuclear power. I'm not sure that that is a role of this committee or not.

I would say, Mrs. Lloyd, I do want to compliment——

Mrs. LLOYD. Here we can't convince Mr. Stockman that we need to do this sort of thing.

Dr. WOLFE. Well, I understand your problem, but I feel my responsibility is to put the issues to you, and recognize that perhaps they aren't easily solved.

I do want to indicate my appreciation, and those in the nuclear business, for your support of the nuclear option, and my belief that really the activities in developing reactors for the future are one thing that does indicate to the public at least some faith in the future needs of nuclear power. So I think that that is helpful, but I don't want to leave without again stating the perspective that the present problems really have to be solved, and I recognize——

Mrs. LLOYD. Would you comment on the fact that German nuclear reactor plants have reliability factors of 82 percent versus 64 percent in this country?

Dr. WOLFE. Yes. Our best plant is one in Switzerland, a boiling water reactor that we built. It's being operated in Switzerland.

Our Japanese plants, the ones that we built in Japan, and the Japanese plants that our licensees built, are now again beginning—are now beginning to have better performance than ours. I think, again, it reflects on the type of licensing activity that we have in this country versus what they have abroad.

I take some issue with Mr. Young on his Swedish—saying that the Swedish regulatory people are as rigorous as here. I don't doubt that they are as safety conscious as ours, but I don't think that we have the continuous regulatory pressures on our utilities on items that may have very little to do with safety that really do impinge on the performance of the plant. So I think there's a big—I think you have to go, when you compare these, to the actual conditions in each of the countries. I might say—and I don't want to excuse all the utilities or even all the vendors, but you have to go from utility to utility if you're going to make broad comparisons and compare Mr. Arnold's reactors to mine or to Combustions' or someone elses.

Mrs. LLOYD. Dr. Arnold?

Dr. ARNOLD. I'd like to add I do agree with Bert about the Swedish situation. We did build three PWR's in Sweden and had direct experience with the scene there. I agree with Jack Young about the difficulty of the public perceptual climate, but I would say I agree with Bert Wolfe that there's nobody quite as nit-picky as our own regulators.

What I wanted to say was that, as an old-line reactor developer, I respond with enthusiasm and delight to the idea of new reactors such as PIUS, and even to new variations on old reactors such as the HTGR.

I would, however, caution us as a nation against having a start-and-stop nuclear program on personally what I think is high priority efforts, such as the base breeder programs. I believe that, for example, the zeroing out of BRET is a major catastrophe.

Mrs. LLOYD. I wanted to ask you, how important to your design efforts is a breeder fuel cycle program?

Dr. ARNOLD. Our version of the advanced breeder is quite similar to Dr. Till's except it uses oxide fuel. We have published a conceptual design of what we feel is a low-cost plant which combines reactor and fuel cycle in one location and eliminates a lot of proliferation concerns, and we also think it's competitive in cost. But it requires as part of its development the proceeding with BRET and the SAF line program as the key parts of the demonstration that you can close the fuel cycle in one location.

I want to heartily say that we should not suffer from the problem of a start-and-stop program in our major programs. If we start a program like a base breeder program, we ought to keep it going.

Mrs. LLOYD. In May of last year I sent a letter to the Department, to Dr. Brewer, requesting that he consider the merits of initiating a program that closely couples complete fuel recovery capability with the breeder reactor, and I referred to the FFTF and FMEF complex.

Dr. Till, why didn't the Department at that time inform us of your work in this area?

Dr. TILL. We weren't, in fact, working in the area at that time, Madam Chairman. We were doing work on the pool concept, and it was only toward the—oh, really in the fall of this year that we took the next steps into the whole integral cycle.

Mrs. LLOYD. So this is not anything that you were involved in in May of last year?

Dr. TILL. No, we were not.

Mrs. LLOYD. We've been emphasizing the need for inherent safety and low capital cost for future nuclear powerplant designs. How are each of you addressing these features in your reactor design work?

Dr. TILL. Let me comment first, if I may.

The whole driving force of the design was just that—first, on the inherent safety, but to make the features easily identifiable, easily proven, not subject to a requirement for very complex calculation codes, things difficult to point to.

Mrs. LLOYD. Do you see the economics of the small reactor?

Dr. TILL. That is a question, again, that everybody today, I've noticed, has said on one hand and on the other, and I feel very much the same way. It's difficult for me to get around the simple fact that for most things, including reactors, there is economy of scale. But I do think that, with the kind of simplifications in design that are possible in the sodium-cooled system, that one can make smaller reactors economic. But, again, as I said earlier, just how competitive, until we've done——

Mrs. LLOYD. We're going to go from "Y" to "A" this time.

Mr. YOUNG. Madam Chairman, on the economics on PIUS, we'll know more about that as TVA reviews the cost estimate of certain of the key elements of PIUS, such as the constructability of the pressure vessel, and the costs have been examined by SKANSKA, which is the largest construction firm in Sweden.

I think one issue on the light water reactor, the ASEA program is at the stage of maturation. It's a mature program, and it's something that all countries strive for, all manufacturers strive for. "How can I get a series of reactors put online, and will they operate reliably; will they operate within the regulatory frame?"

Looking at Sweden, for example, we have Westinghouse reactors, as Howard Arnold had mentioned, and they're having a tough time in the same regulatory environment. They are newer, but they do have one plant online since 1975, but they have gone through—and they are continuing to go through—the kind of trauma we have in the United States, and the ASEA plants are not, operating under the same regulatory environment.

Dr. **Arnold**. I would differ on the same kind of trauma. The PWR's we have in Sweden are undergoing some of the same worldwide service issues that we have, but the operating records are above the U.S. average.

Mrs. **Lloyd**. Well, I want to know how are you addressing these features in your reactor design, in your breeders.

Dr. **Arnold**. In the breeder?

Mrs. **Lloyd**. Yes, sir.

Dr. **Arnold**. Well, our prime contender for a conceptual design of a low-cost breeder is a plant which has the highest degree of factory construction of the parts of the plant. It makes use of the safety features of the low pressure and the natural circulation to not require a large containment vessel, so we believe that you can save a great deal of concrete and steel. And it involves the combination of the plant with its associated fuel cycle. Some of the same reasons Dr. Till mentioned would make the entire breeder cycle much more acceptable, if you were not, in fact, shipping plutonium from here to there but have one single complex in which the entire fuel cycle is closed. We believe that has a chance, at least, of being done economically, and we believe there ought to be substantial development on that in the U.S. breeder program.

Mrs. **Lloyd**. Mr. Williams?

Mr. **Williams**. Well, we have worked, as I mentioned, with Argonne and with CE in looking at these plants. I think, as Dr. Till mentioned, as we come down in size, it is more difficult for us. Right now, with the studies we've had, probably below 300 megawatts is much more difficult for us to quantify and say that we can match some other plant, but now we're starting to compare 300 megawatts or plants lower than that with what other things are on the market. So it's a difficult point for us after we start to drop below 300 megawatts. But down to about 300 megawatts, if we look at the design features we are getting in there, the smaller plant footprints, the amount of materials, and so on, the scaling that we've done there suggests that we can show ourselves competitive with both the light water reactors and coal that you might scale in those two areas.

I think the area that Dr. Till hesitated on was we are just looking simply at scaling the plants, and the cost figures on those are fairly good. But when we add the reprocessing facility in addition to that, we have not gone through those features yet.

I think, as Chuck did point out, that is not a new concept. The EBR-II started out with that concept in the very early 1960's, which was really an outgrowth of the technology work that we were doing in the 1950's, and both we and Argonne at that time had done a lot with the on-plant-site reprocessing of fuel.

I think the thing that we're looking at, particularly with the promise of the metallic fuel, suggests that there are a lot of ways in which this plant might be incorporated into future designs, and so focusing a lot of dollars on one particular thing when we still might not be too sure which fuel element we might have would suggest not making the biggest investment in a particular reprocessing technology until we have done more studies on that.

But specific things that can make quite an impact on plant size—for example, a pump seems like perhaps a trivial item, and yet the smaller you make that pump, the smaller everything that's associated with it gets, and it can really pull down the size of the plant; therefore, the amount of components that have to support that.

Some of the advanced things, we have been—I think this committee, through some of its other efforts, supports a lot of things in the aerospace side of the business and has supported the development of some very advanced technology pumps. We've taken advantage of those, incorporated some of those features into the sodium pumps, and are finding we can get tremendous performance out of sodium pumps which are not achievable in other configurations.

That's an area where I think the committee has already supported work which we're translating and which could be further supported to enhance that.

I think steam generators, again, are an area where we constantly recognize that that's certainly the thing that gets the most attention throughout the light water industry, and we think it's an area that has always been central to our thinking in terms of the reliability and capability of the plant. So a continuing effort in supporting the development in those areas is very important in terms of what we see in terms of being able to pull the plant costs down.

Mrs. LLOYD. Thank you.

Dr. Wolfe, in your statement you address the role that advanced R&D programs could play in reinvigorating the nuclear option in the development of advanced nuclear powerplants for the future. Correct me if I'm wrong, but wasn't GE a driving force behind the modular HTGR program?

Dr. WOLFE. Yes, we have been. As I said, the modular breeder—we believe that these, as I said before, are the ways to develop these concepts, the HTGR and the breeder, so that the Nation can afford it and so that the process of development converges.

Mrs. LLOYD. Well, I had a letter from Mr. Richards in December, formerly of GE, as you know. He said of the modular HTGR program, he said that funds should be allocated for 3 years at a level of at least $20 to $25 million a year. I just want to know if GE had had a change of heart on the modular HTGR since Mr. Richards sent his letter.

Dr. WOLFE. My testimony was not to indicate lack of enthusiasm for HTGR or the modular breeder, and I share Howard's feelings that we should be moving—not stopping and starting on the breeder program, but we did have some concern, in particular the letter you sent us which indicated that these advanced programs could reinvigorate the nuclear business. We had some concerns that we would be misrepresenting our position, and it seems to me the industry would be misrepresented or would not benefit, if we implied, despite the enthusiasm for these new concepts, that they were the way to fix the nuclear industry. We do not believe that the light water reactor is deficient as a concept. We think it can be made to be, and has been demonstrated to be, a safe, efficient, low-cost source of power, and we really believe we have to fix up our industry. And if these advanced concepts are used to take our eye off of that problem, I think they'll do a disservice. That's really the point that I was trying to make.

With respect to the question on what we're doing on economics, on the modular breeder where we have looked in some detail, at least with the rough concepts we have, we have had cost estimates done by United Engineers, and it turned out so low that I don't even want to discuss them. But they did indicate that there was great promise there.

What you have to do is you do have the law of scale working against you, and what you have to do is to use the inherent features of small size to get some features that outweigh the law of scale. In the case of both the modular HTGR and the modular breeder, the feature—two features that we took, both are factory fabricated and shipped to the site. We think that's a factor.

Second, both of them are designed so that natural circulation, air, is the final heat dump under emergency conditions. They are both self-contained in the nuclear module so that, if—so that in an accident you can shutdown and it may even be that you don't have to shutdown, but you can shutdown and walk away; and they both have internal steam generators, so that the balance of plant can be made on the basis of conventional construction practices.

So those kinds of features which we get in small size we hope will outweigh the scale effect, and at least on a preliminary look—and I don't take any of these preliminary studies seriously except to say they say that you ought to keep going. It looks very favorable.

Mrs. LLOYD. I'd like to ask the staff if they have any questions to present to you.

Mr. RON WILLIAMS. Thank you, Madam Chairman.

Dr. Wolfe, you didn't recite it this afternoon, but in your written testimony you had a comment concerning the corrosion of fuel elements in a gas reactor, because of the carbon dioxide and magnesium fuel element coatings. My question is, Was that directed toward a British reactor in the 1950's and not an HTGR, as you understand it?

Dr. WOLFE. Oh, yes, certainly. I recited in that testimony seven or eight deficiencies that were found both in BWR's and in PWR's, the gas reactors and heavy water reactors, and the point of that argument was that it took 20 years or so in many of those cases to find those fundamental problems. I would be surprised if we didn't find those problems in HTGR's, whether they're GE's or GA's, or in liquid metal reactors, whether they're—whoever's they are at this table. I think it would be foolhardy to go ahead without expecting to find some surprises. It seems to me the nice thing that we've found so far is that none of these bad surprises—we've found some good ones, but none of the bad surprises—have been fatal to any of the concepts, and particularly with the large experience with the light water reactor, even with the problems we found there, all of the problems seemed to be correctable.

But my point was not to pick that gas reactor as a symbol because it is a British Magnox reactor where that happened.

On the HTGR, for example, we did find that when it started up that the fuel elements moved in strange ways initially. That was just a start. We did have some problems starting up. I would be surprised if after 10 years they didn't find some things that weren't expected for them that would have to be modified. That is really the point I was trying to make.

Mr. RON WILLIAMS. Thank you.

Dr. Arnold, the question of the British switching from a gas reactor to a PWR, and you referred to Sizewell-B, were there many additional safety features that the British Government insisted be put on that plant, as opposed to some of our plants?

Dr. ARNOLD. We have in Sizewell-B a revised safety system which is also similar to the one that we're putting on our advanced PWR in Japan. Whether you would say it is something the British insisted on, I don't know. That's a matter of debate. It's our response to the many years of what I would call ratcheting and trying to start with a design that, in fact, had separate safety systems and more of them. Our clean sheet today is safety design. Yes, the British welcome them with open arms; the Japanese like it in the advanced PWR; and we would hope eventually to sell it here in the United States.

Mr. RON WILLIAMS. Do you have a construction permit yet?

Dr. ARNOLD. For which?

Mr. RON WILLIAMS. Sizewell-B?

Dr. ARNOLD. No, Sizewell-B is in the middle of its public inquiry, and that process is not complete.

Mr. RON WILLIAMS. Mr. Williams—when you talk about modules and shop fabrication, could you see a situation where not only the nuclear steam supply system was shop fabricated, but perhaps also the control room, a complete control room and a complete secondary system, and of course the turbine generator?

Mr. WILLIAMS. Do you mean the entire plant shop fabricated?

Mr. RON WILLIAMS. In four separate modules.

Mr. WILLIAMS. Oh, in separate modules?

Mr. RON WILLIAMS. Right.

Mr. WILLIAMS. Well, certainly there is a lot of work that goes on in building up modules. I could see, principally in the reactor end of it, very clear the ability there to modularize, and that portability—I think we've talked about the size there depends a whole lot on whether you're talking about rail or barge shipment, in terms of which plants you can handle that way.

There is a lot that we, and I know the others, build as complete systems and test out in our own shops before we ship them, for example, in the controls areas. A lot of those things are handled that way.

Mr. RON WILLIAMS. Do you think it may enhance the quality——

Mr. WILLIAMS. Conceptually, they could, and certainly anything that we can do to check out before we ship it to any site is always an enhancement in terms of knowing what you have as a delivered product, rather than field wiring and things like that.

Mr. RON WILLIAMS. Do you think if we had similar—in fact, identical—control rooms, that that would enhance operator performance?

Mr. WILLIAMS. In terms of the ability to have individual common features in control rooms, and not having to relearn, and so on, that is an important factor.

Mr. RON WILLIAMS. Thank you.

Thank you, Madam Chairman.

Mrs. LLOYD. Thank you very much, Mr. Williams.

I want to thank you as a panel and individually for your time. You've been very generous with us, and we are very grateful.

I think now we do have a vote pending, and so we will recess our hearings for about 15 minutes. Everyone can take a nice stretch.

[Recess.]

Mrs. LLOYD. The committee will resume its hearings.

Our next witness will be Dr. William Wright, who is with the Defense Advanced Research Projects Agency.

We welcome you, Dr. Wright. You may proceed with your testimony or summarize. Proceed as you wish.

STATEMENT OF DR. WILLIAM E. WRIGHT, DIRECTOR, DOE-NASA-DOD SPACE NUCLEAR POWER PROGRAM, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

Dr. WRIGHT. Thank you.

My name is William E. Wright. I'm the Director of the SP-100 Space Nuclear Power Program, and in that capacity I have responsibilities to the Department of Energy, to NASA, as well as to the Department of Defense.

I'm delighted to have the opportunity to describe to you the progress of plans for the SP-100 space nuclear power program at this time.

The appearance and clearer definition of new reactor power system requirements for potential military and civil terrestrial applications as well as for space seems to me to be a common theme occurring through today's hearings.

In its first year the SP-100 organization has been very busy. Our major upcoming milestone is the selection of a specific concept for engineering development and ground tests. We must make that selection and demonstrate the basic feasibility of that concept by the end of fiscal year 1985. All work is on schedule, and I am confident that we will be prepared for an engineering development and ground test program starting in fiscal year 1986.

In studies with the Air Force, Navy, and NASA, it has become very clear that there are emerging three major generic missions which are apt to be the first users of space nuclear reactor power. These are communications satellites for both commercial and military use, radar surveillance, and remote sensing satellites for civil and military applications, and a power system to support manufacturing and other aspects of a growth space station.

There are many other applications we will continue to examine, of course, but these three are emerging as the dominant near-term missions and will be used to guide the program.

Now we chose specific power system requirements to maximize performance for a number of these potential missions while calling for only a modest advance in technology. We feel that this maximizes the potential support for future space missions for space nuclear power.

Following that, we have screened potential space nuclear power system concepts carefully on the basis of their ability to meet the system requirements and on the basis of technology risk. We have now narrowed the field to three which appear to meet these requirements with a reasonable balance of technical risk and development time.

This narrower from more than 100 potential concepts to three, and eventually to one, is mandatory if we are to achieve our objective of development and use of a space power system.

We feel that we have an appropriate balance for this point in the program, enough system concepts under consideration to allow for fallback in case of technology failure, and few enough concepts to allow for concentration of resources.

Our current concepts include a lithium-cooled reactor with thermoelectrics, an in-core thermionic design, and the Sterling engine for use with lower-risk reactors and for growth with higher temperature systems.

We also have available to us low-risk backup approaches which require little, if any, technology development. These concepts, not surprisingly, also have considerably less performance and almost no growth potential. They would only be used in the event of an urgent requirement for some space mission. No such requirement exists, and I do not have any indication that one is likely to come up.

Therefore, we have the time to advance technology and to provide a system with considerable growth capability to match the evolving space needs of the future.

Technology validation experiments, tests, and analyses are now underway on all of the technical issues relating to our three concepts. These are timed to provide feasibility answers by mid-1985, to support final selection of the concept for engineering development. I must emphasize, however, that these experiments and testing programs are not the complete detailed ones required to obtain precise engineering data. The current program does not cover a range of tests at, say, a series of temperatures, operating conditions, and excursions. Rather, it is point tests at single operating parameters. Under the current plan we do not initiate that level of activity until the beginning of the engineering development phase in 1986. The current tests are designed to determine feasibility only, and that is the objective of this current phase.

The objective of the next phase is to complete all engineering development and ground-test activities needed before prototype flight units could be assembled and qualified for first flight applications. In laying out potential programs for that next phase we have three fundamental concerns:

First, work on that phase must establish with a high degree of certainty that any system will, in fact, meet safety criteria. That's No. 1.

Second, the next phase must also obtain necessary engineering data and produce designs with high confidence of meeting mission requirements and demonstrate those designs on the ground.

Finally, we are intent on keeping the scope and cost of the engineering development and ground test phase to a minimum, consistent with the first two principles.

My deputies from the Department of Energy and NASA and I are fully confident that all engineering development and ground test activities necessary to meet these objectives and to prepare for first flight applications can be conducted in approximately 5 years. Early estimates indicate that the essential elements of such a program could be carried out for a minimum investment of approximately $350 million starting in 1986.

A commitment to a flight application phase could be made, then, as early as fiscal year 1988 or as late as fiscal year 1991 without disrupting the development flow.

The funding would probably be shared between the Department of Energy, NASA, and the Department of Defense. We are currently working hard to insure that the necessary funding is in place for the second phase in each of the three fiscal year 1986 budgets.

Over the next year the details of the program plans and cost projections will be carefully developed by SP-100 with the active involvement of the funding agencies and potential users.

Your letter expressed a particular interest in the role that advanced reactor development might play in reinvigorating nuclear power as an option in this country. That's a difficult area for me to address effectively in detail, since my experience is principally limited to the SP-100 program, but I do have some general observations which might bear on the subject.

In the past year I have heard of many concepts involving compact advanced reactors in addition to space nuclear power. There seem to be some common threads running through these exciting new ideas which relate to our experience in SP-100. Let me explain.

First, I hear of a great interest in truly listening to and working with potential users. If the SP-100 program is to be successful, it will only be because we are developing technology in parallel with careful pursuit of understanding of space missions and users. In other words, we are trying hard to anticipate and respond to the market, rather than trying to make the market bend to our prejudices in favored technologies.

Second, I see what appears to be a number of interesting ideas and opportunities for a very broad base of potential customers. I have already explained that my deputies and I are convinced that engineering development of space nuclear power need not be a very large or a very long-term undertaking. It seems to me that many of the ideas I have heard lately are similar. Few would seem to require massive commitment of material, financial, human, or facility resources. Moreover, the theme of compactness and modularity seems to pervade.

To me, this seems to be a very healthy situation in which a number of independent, yet possibly mutually supportive, development activities can be carried on leading to a wide range of products and markets.

Mrs. Lloyd. Excuse me, Dr. Wright. We have another vote.

We will again stand in recess.

[Recess.]

Mrs. Lloyd. The committee will resume its hearing. My apologies to you, Dr. Wright, for cutting you off in the middle of your statement, but that is some of the procedures that seem to evolve in this body.

Please proceed.

Dr. Wright. Thank you, Madam Chairman.

As I was starting to say, there appear to me to be three common threads running through the advanced reactors we've been hearing about today and the SP–100 program. The first two of those I have described. Finally, there's an area of concern to me in the SP–100 program which may be a problem to some of these other activities as well.

In trying to obtain levels of performance attractive to potential users, we have gone to the technology cupboard and found it nearly bare. It's well known that the termination of the previous space nuclear power program in 1972 was very disruptive, but I did not realize that so little basic technology work continued in areas critical to this and to other applications.

For example, we are not in SP–100 trying to invent new clads and new fuels. Rather, we are simply trying to characterize in the high temperature regime that we require the behavior of fuels and materials which have existed for years and even decades.

Long-term measurement tests and technology programs, which I thought might have been going on in laboratories and universities across the country, were not. Had it not been for the dedication of some of the experts in places like Oak Ridge, all of the past capability in critical areas such as refractory alloys might also have been lost.

I'm concerned that many of the other good ideas people are suggesting we carry forward may rely on data from nonexistent technology based programs.

On the positive side, as an example, we did have a very small continuing program in advanced high-power, high temperature heat pipe technology at Los Alamos. Now it appears that those heat pipes probably won't be used in the interior of space reactors as originally envisioned. However, most of the system concepts we have seen call for the use of such heat pipes in radiator and other space components. Were it not for the small, ongoing program at Los Alamos and the internally-supported work of one or two contractors, we would have major technical uncertainties on our hands.

Other important examples are NASA's Jet Propulsion Laboratory for thermoelectrics and the NASA Lewis Research Center and the Air Force's Air Propulsion Laboratory for dynamic machinery.

The Office of Science and Technology Policy and others have suggested that an appropriate redirection for our laboratories is toward long-range research on technology suitable for a number of applications. Perhaps something like this will be required if these advanced reactor concepts are to be turned into reality.

It seems to me, then, that a future nuclear industry could be formed on a very broad base of system concepts aimed at carefully-defined markets and users. These activities, if supported by a similarly broad base of aggressive, advanced technology programs designed for the long haul, might help to regain the dynamic nuclear industry. I hope that SP–100 is a positive sign for the coming era.

Thank you for the opportunity to speak to you on space nuclear power.

[The prepared statement of Dr. Wright follows:]

PREPARED STATEMENT OF DR. WILLIAM E. WRIGHT, DIRECTOR, DOE-NASA-DOD SPACE NUCLEAR POWER PROGRAM (SP-100), DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

MADAM CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE:

I can think of no better time to appear before this subcommittee than now. The space nuclear power program is well underway and exciting new uses for new types of nuclear power reactors appear to be emerging. Nearly one year ago the Department of Energy, the National Aeronautics and Space Administration, and the Defense Advanced Research Projects Agency embarked on the development of space nuclear power, and I am delighted to have the opportunity to describe to you our progress and plans. Perhaps more significantly, civil and military space missions requiring or greatly benefiting from space nuclear power are becoming more and more clear. The appearance and clearer defintion of new reactor power system requirements for potential military and civil terrestrial applications as well as for space seems to me to be a common theme. I will return to this theme and some views on the importance of understanding these potential markets near the conclusion of my remarks.

Perhaps before we begin I should explain my responsibilities and resulting perspective on space nuclear power. My position as Director of the SP-100 Program is somewhat unusual. While I report administratively to the Director of DARPA, I receive programmatic guidance and direction from a senior-level steering committee representing DOE and NASA as well as DOD. My duties transcend those one might expect -- I am personally responsible to the Steering Committee for ensuring that any technologies, power system concepts, and programs my staff and I pursue support both civil and military missions, are safe, and follow the principals of sound nuclear and space engineering and technology. In the sense of my responsibilities to all three organizations, I am appearing before you today as a representative of the Department of Energy and NASA as well as the Department of Defense.

I would first like to review the progress, status, and plans for the space nuclear power program and then to turn to some observations on the areas of particular concern to this subcommittee as expressed in your letter of invitation.

You may recall that DOE, NASA, and DARPA signed a Memorandum of Agreement establishing the SP-100 Program in February, 1983. I am the Director of the Program Office and, supported by my two deputies from DOE and NASA, provide technical and programmatic direction to the SP-100 Project Office at the Jet

Propulsion Laboratory. The SP-100 Project Office draws its nuclear expertise from the Deputy Project Manager for Nuclear Technology and his staff at Los Alamos National Laboratory.

The tasks of the SP-100 organization in its first year have included detailed program, objective, and role definition, civil and military mission analysis, space nuclear power system functional requirement definition, conclusion of initial space nuclear power system concept definition studies, selection of primary concepts for technology feasibility validation, defining and initiating specific technology programs and objectives to support the system concepts, and obtaining initial experimental and analytic results. These activities are proceeding rapidly towards our major milestone: selection of a specific concept recommendation for engineering development and ground test and demonstrating the basic feasibility of that concept by the end of fiscal 85. All activities are on schedule and I am confident that we will be prepared for an engineering development and ground test program starting in FY86.

Initiating such a wide range of activities is never easy, particularly when the task of properly addressing the legitimate concerns and interests of the three different sponsoring agencies is considered. I am happy to report that the hard work, dedication, and enthusiasm of the first-rate professional and technical members of our team are making the SP-100 organization we put on paper last year work very well indeed; the best measure of success is the progress I will describe to you shortly. Moreover, we are making this progress by drawing on the strongest capabilities of DOE, NASA, and DOD and their field organizations. The solid backing and support we enjoy from each of the three agencies has also been central to our progress to date. I feel that we are building credibility and respect within our parent organizations as the technical work performed by our project office and contractors is seen to be increasingly sound and professional.

The strategy of the SP-100 Program is to first identify potential users and space applications and then to determine power system functional requirements from mission requirements. We then define system concepts to meet the functional requirements within safety and other constraints, define critical technical issues for these concepts, and then verify through analysis and experiment solutions to these technical issues. Of course, a number of these activities overlap in time. We feel that this process assures that any system and technology we recommend for development will meet the emerging needs of civil and military space users.

The SP-100 Program is conducting a number of studies with Air Force, Navy, and NASA participation to examine future space missions which could require nuclear power. In the past year it has become very clear that there are three major generic missions which are apt to be the first users of space nuclear reactor power. These are communications satellites for both commercial and military use, radar (and possibly laser radar) surveillance and remote sensing satellites for civil and military applications, and a power system to support manufacturing and other aspects of a growth space station. There are, of course, many other applications we will continue to examine, but these three are emerging as the dominant near-term missions and will be used to guide the program. In fact, by the time we are ready to begin engineering development and ground testing in FY86 I expect that these generic mission areas will be defined to the point where we can expect strong user support in proceeding.

We have derived power system functional requirements with the aid of potential users to support these and other missions. The functional requirements, determined in an iterative process, will be made firm for the remainder of the technology phase within the next month or two. Specific requirements range from general ones, such as 3000 Kilogram maximum mass and ability to fit in the shuttle bay with a payload and an orbital transfer vehicle, to specific details of radiation fluxes on the payload and electrical load-following capabilities. We chose these requirements to maximize performance for a number of potential missions while calling for only a modest advance in technology. We feel that this maximizes support for future space missions while minimizing the number of other inventions required to capitalize on space nuclear power. For example, for special purpose applications we can always increase the mass of our system without changing the technology. This could lead to a full megawatt system in a single shuttle launch suitable for assembling to the payload on orbit. But, in general, most users will prefer the more economical approach of single-launch space systems if they can meet their mission requirements within the launch volume and mass constraints.

Following careful screening of many potential space nuclear power system concepts we have now narrowed the field to three which appear to meet these requirements with a reasonable balance of technical risk and development time. This relentless narrowing from over 100 potential concepts to three and eventually to one is mandatory if we are to achieve our true objective of development and use of a space power system. We feel that we have an appropriate balance for this point in the program - enough system concepts under consideration to allow for fallback in case of technology failure and few enough concepts to allow for concentration of resources. It is always possible after a baseline system has been developed and is in use to improve it through new technologies or to reconsider alternate approaches. For now, however, we must continue to focus down to the one concept we will develop to meet emerging user needs.

The first of our three current concepts uses a fast lithium-cooled reactor coupled to thermoelectrics. The coolant is pumped with electromagnetic pumps. Heat is transferred to thermoelectric elements radiatively to avoid excessive thermo-mechanical stresses on the thermoelectrics. Waste heat is removed through a heat pipe distribution system and space radiator. The principal technical uncertainties are the compatibility of fuel, clad, and lithium coolant, fuel properties in the temperature and burn-up range of interest, and the performance and long-term behavior of the thermoelectrics at high temperatures. Potential advantages of this approach are relative lack of moving parts and the proven use of similar but not identical thermoelectrics in RTG's in many spacecraft.

The second approach is an in-core thermionic system with a pumped sodium-potassium coolant. Advantages of such a system are overall simplicity, past in-core data on thermionic elements for limited lifetimes, and relatively little mass and size growth for higher powers. An unanswered question is whether the increased non-nuclear material and large thermionic gaps required in the core to sustain long-life operation forces the overall concept to be excessively massive in the lower power regime. Specific technical issues are fuel swelling rates and mechanisms and insulator material lifetimes in the required temperature and flux regime.

The final approach we are working on uses a Stirling engine to convert reactor heat into electricity. Since it has potentially much higher conversion efficiency than the other approaches, reactor temperatures could be significantly reduced for the same power. Conversely, it could provide substantial growth capability for a high temperature reactor. Here the issues involve the Stirling engine itself and include high temperature, long-life performance, ability to provide high efficiency with a relatively low temperature drop, mass reduction, and dynamic balancing so that vibrations don't affect space system operations.

We also have available low risk backup approaches. They require little, if any, technology development and could shorten the required engineering development phase somewhat. These concepts, not surprisingly, also have considerably less performance and no almost growth potential, and would only be used in the event of an urgent requirement for some space mission. No such requirement exists, nor do I have any indication that one is likely to come up. Therefore we have the ability to advance technology and to provide a system with considerable growth capability to match the evolving space needs of the future.

All of these concepts rely heavily on the heritage of technology from the previous space nuclear power program and other nuclear reactor development activities. In most cases, however, we need to step beyond what is known with certainly to obtain attractive system performance. Technology validation experiments, tests, and analyses are now underway on all of the technical issues I described earlier. These are timed to provide feasibility answers by mid-1985 to support final selection of the concept for engineering development, with many intermediate results earlier. It should be emphasized, however, that these experiments and testing programs are not the complete detailed ones required to obtain exact engineering data to support designs with small tolerances and highly accurate performance predictions. The current program does not cover such a range of tests at, say, a series of temperatures, operating conditions, and excursions. Under the current plan we do not initiate that level of activity until the beginning of the engineering development phase in FY86. The current tests are designed to determine feasibility only — and that is the objective of this phase.

However, we are rapidly approaching the start of engineering development activities in FY86. My colleagues in the program and project offices and I are preparing for this increase in the pace of the program by beginning to define those activities needed in transition. Specifically, we are now defining specific engineering development and ground test activities and schedules required. The objective of this next phase is to complete all activities needed before protoflight units could be assembled and qualified for first flight applications. To meet this objective the next phase must develop and test all major subsystems and must verify through analysis and experiment as appropriate the safety of our selected concept under all relevant conditions. Space qualification at the component and subsystem levels must also be completed.

In laying out potential programs for the next phase we have three fundamental principles. First, the next phase must establish with a high degree of certainty that any system will in fact meet safety criteria. Second, the next phase must obtain necessary engineering data and produce designs with high confidence of meeting mission requirements. Only by providing systems and results commensurate with the high standards of the space and nuclear industries can we be certain of meeting the space system user's -- our customer's -- needs. Finally, we are intent on keeping the scope and cost of the engineering development and ground test phase to a minimum consistent with the first two principles.

This bears clarifying. We are designing a second phase which will do all that is necessary to demonstrate to ourselves and to the public that any space nuclear reactor power system subsequently built, launched, and used will be safe. We will put into the second phase all that is necessary to deliver a sound product which the user can count on. But we will work hard to confine the program to that which is necessary, to avoid redundant or unnecessary tests and facilities, and to control costs. My deputies from the Department of Energy and NASA and I are fully confident that all engineering development and ground test activities necessary to meet these objectives and to prepare for first flight applications can be conducted in approximately 5 years. Early estimates indicate that the essential elements of such a program could be carried out for a minimum investment of approximately $350 million starting in FY86. A commitment to a flight application phase could be made as early as FY88 or as late as FY91 without disrupting the development flow. The funding requirements would probably be shared between DOE, NASA, and DOD over the 5 year life of the development program. We are currently working hard to ensure that the necessary funding is in place in each of three FY86 budgets. Over the next year the details of the program plans and cost projections will be carefully developed by the SP-100 project office with the active involvement of the funding agencies and potential users.

While my deputies and I are certain that the engineering development and ground test program can be conducted on the timescale and for the funding described, we are also certain that there will be numerous suggestions to continue development of alternate systems and to expand technology and test programs. Once we are certain that we have a proposed program which will meet the safety and performance needs fully, we will work very hard to minimize growth by restricting the addition of more tasks. Another way to minimize growth is to take every advantage of existing facilities and capabilities and past development activities. A very focused and disciplined approach to the program will be required.

Your letter expressed a particular interest in the role advanced reactor development might play in reinvigorating nuclear power as an option in this country. That is a difficult area for me to address effectively in detail, but I do have some general observations which might bear on the subject. In the past year I have heard of many concepts involving compact, advanced reactors in addition to space nuclear power. You are hearing about most if not all of these today. There seem to be some common threads running through these exciting new ideas. Let me explain.

First, I hear of a great interest in truly listening to and working with potential users. What might be the requirements for secure power and remote basing? Is nuclear power a reasonable alternative? What, if any, interest might the manufacturing sector have in its own power sources? Under what conditions might nuclear power prove attractive to a manufacturing corporation?

Can nuclear technology actually meet those conditions? I hear similar questions more and more. If the SP-100 Program is to be successful it is only because we are developing technology in parallel with careful pursuit of understanding of space missions and users. In other words, we are trying hard to anticipate and respond to the market rather than trying to make the market bend to our prejudices and favorite technologies. Market analysis and development is crucial to almost any human endeavor.

Second, I see what appears to be a number of excellent ideas and opportunities with a very broad base of potential customers. I have already explained that my deputies and I are convinced that engineering development of space nuclear power need not be a very large or long-term undertaking. It seems to me that many of the ideas I have heard lately are similar. Some are quick reaction activities, others may take longer, but few would seem to require massive commitment of material, financial, human, and facility resources. Moreover, the theme of compactness and modularity seems to pervade. To me this seems to be a very healthy situation in which a number of independent yet possibly mutually supportive development activities can be carried on leading to a wide range of products and markets. This broader base is certainly healthier and more stable than placing all of our nuclear resources on one or two massive programs. It is certainly easier to absorb the loss of one or two markets if we are pursuing a dozen.

Finally, there is an area of concern to me in the SP-100 Program which may well be a problem for some of these other activities as well. In trying to obtain levels of performance attractive to potential users we have gone to the technology cupboard -- and found it nearly bare. It is well known that the termination of the previous space nuclear power program in 1972 was all-inclusive and disruptive, but I did not realize that so little basic technology work continued in areas critical to this and other applications. For example, we are not in SP-100 trying to invent new clad materials and fuels; rather, we are trying to characterize at the high temperature regime we require the behavior of fuels and materials which have existed for years and even decades. The long term measurement, test, and technology programs which I thought might have been going on in laboratories and universities across the country were not. Had it not been for the dedication of some of the top-notch people at places like Oak Ridge, all the past capability in critical areas such as refractory alloys might also have been lost. I am concerned that many of the other good ideas people are suggesting we carry forward may also rely on data from non-existent technology base programs. As an example, the positive side we did have a very small continuing program in advanced, high power, high temperature heat pipe technology at Los Alamos. Now it appears those heat pipes probably won't be used in the interior of space reactors as originally envisioned. However, most of the system concepts we have seen call for the use of such heat pipes in the radiator and other heat transport systems. Were it not for the small, ongoing program at Los Alamos and the internally supported work of one or two contractors, we would have major technical uncertainties on our hands. Other important examples are Oak Ridge National Laboratory for refractory alloys, JPL for thermoelectrics, and NASA Lewis Research Center for dynamic machinery. The Office of Science and Technology Policy (OSTP) has suggested that a very appropriate redirection for our national and other laboratories is towards long range research on the leading edges of technologies suitable for a number of applications. Perhaps something like this will be required if a number of advanced reactor concepts are to be turned into reality. The nuclear community will certainly become smaller in the coming years; it could also become healthier through restructuring and redirection.

It seems to me, then, that a future nuclear industry could be formed on a very broad base of system concepts aimed at carefully-defined markets and users. These activities, if supported by a similarly broad base of aggressive, advanced technology programs designed for the long haul, might help to regain the dynamic nuclear industry we seek. I hope that SP-100 is a positive sign for the coming era.

Mrs. **Lloyd.** Well, thank you, Dr. Wright.

I think that we're going to have Dr. Boudreau also testify, and then we'll come back for questions.

We welcome you to our hearing, Dr. Boudreau.

You may proceed as you wish and summarize your statement, and it will all be made a part of the record.

STATEMENT OF DR. JAY E. BOUDREAU, DEPUTY ASSOCIATE DIRECTOR, NUCLEAR PROGRAMS, LOS ALAMOS NATIONAL LABORATORY

Dr. **Boudreau.** Thank you, Madam Chairman.

Mrs. **Lloyd.** You need to turn on the microphone, please, sir.

Dr. **Boudreau.** Thank you.

Madam Chairman, members of the committee, and distinguished colleagues, I am Dr. Jay Boudreau, Deputy Associate Director for Nuclear Programs at Los Alamos National Laboratory.

I have been asked to brief the committee today on Los Alamos program activities in the area of compact reactors for both civilian and defense purposes. While many of these program initiatives are in the very early stages and some have yet to be fully funded, it was felt that the committee would find interest and perhaps even some enthusiasm for the promise that these programs appear to hold for the future of nuclear power in the United States.

If I may, I'd like to highlight three parts of my testimony for the committee.

First, reactors for civilian use; second, reactors for defense uses; and, third, reactors that may have both civilian and defense uses.

First, let's discuss reactors for civil use. In the two days of testimony before the committee, a wide range of proposals for compact or modular reactor technologies has been made. Each concept holds promise for exciting breakthroughs that may make new orders for nuclear power in the United States possible at some time in the future. The pluses and minuses of each concept may vary, however, and it is difficult to choose which is best without having one or several yardsticks with which to measure their use for various applications. With so many different concepts before us, would it not be desirable to begin to centralize our review and to measure the performance and value of each reactor concept against a commonly agreed upon set or sets of measures? At Los Alamos we are working with the DOE in two important areas so that such sets of measures can be identified.

Our ongoing efforts involve work in cooperation with the nuclear industry to evaluate and improve upon the design of their modular breeder concepts.

The other Los Alamos program that could impact the future of commercial nuclear power in the United States, and it is also sponsored by the DOE, is a market survey of a very different kind. This survey does not seek a home for an existing product. Rather, it seeks a customer, identifies his needs, and then allows for a determination of the best product to meet those needs. Specifically, we have formed a small steering group external to Los Alamos to begin the process.

Key members of this steering committee include the vice president and general manager for Kaiser Aluminum, representatives from Wall Street, and the past Chairman of the AEC.

The steering committee will consider electricity generation needs on a very specific basis. If specific electricity needs are identified, our study will seek to identify the conditions under which any energy supply option could be purchased, not just nuclear. We hope to identify such design goals as power range, reliability, cost, leadtime, et cetera.

If technology development needs exist, and if the investment risk is too high for the industry to shoulder alone, the Department has the option to structure its R&D program priorities accordingly.

The industry has the option to proceed with its involvement in the program depending on its perception of investment risk.

The final step in our market survey will be to determine the portion of the defined market that might be captured by the breeder or sodium-cooled reactors.

Now before going on to discuss reactors for defense, I'd like to highlight that, regardless of the details of design, all of the reactors we are discussing during these 2 days have some features that have been the concerns of the U.S. nuclear programs since the beginning. They all strive for inherently safe designs. They all strive to dramatically reduce capital costs. They all seek dramatic reductions on construction time, and so on.

Is it possible that the billions of DOE base technology dollars previously invested in reactor technology can now be exploited to benefit the new reactor initiatives? Can we draw on the people, institutions, knowledge, and private and Government commitment to the breeder program to reestablish nuclear power in the United States? I personally see nothing that prevents it, if that is what the country wants to do.

Now let us switch to topic of reactors for application to purely defense needs. There are two programs here that merit your attention. The first is the so-called defense terrestrial reactor program; the second is reactors for use in the north warning system.

A number of classified studies——

Mrs. Lloyd. Excuse me. Would you repeat that again, Dr. Boudreau?

Dr. Boudreau. Yes.

The two programs are the so-called defense terrestrial reactor program, and the second is reactors for use in the North Warning System.

Mrs. Lloyd. Thank you.

Dr. Boudreau. A number of classified studies have been conducted for the Air Force by Los Alamos to evaluate the desirability of providing an independent and reliable source of electricity for key Air Force bases. Upon review of these reports and others, the Air Force has determined that a more careful technical review of energy supply options for these key bases is desirable. Los Alamos has been asked to submit a program plan through the Department of Energy that would enable construction of a prototype reactor unit within the next 5 years. Should the prototype operation prove successful, the Air Force could then decide whether to more widely deploy such units at other bases. The laboratory has been asked to manage the program and to select between design proposals submitted by industrial contractors in response to a formal request for proposals in the month of March.

While we're very excited about the prospects for the defense terrestrial reactor program, another new program affords challenges of a different kind. The Air Force has an ongoing program to evaluate its needs and technical programs in order to replace the defense early warning or DEWline system. The DEWline was designed to provide surveillance and warning against Soviet attack. The new north warning system program will, as part of its charter, seek to improve certain aspects of the power supply for radar systems that can perform to meet ballistic defense needs.

The power supply for the north warning system will need to provide 5 to 40 kilowatts of electric of continuous and reliable electricity in a completely unattended mode of operation. Our target at this time is 18 months of unattended operation. Power supplies are located in remote portions of the Northern Hemisphere that are difficult to access and that offer a hostile environment for maintenance, repair, refueling, and in general any manned intervention.

A number of power supply options are under review. These include reactors, fuel cells, diesel power supplies, and others. The program at Los Alamos is in its early stages, and we are presently evaluating the different energy supply options against a set of requirements being defined by the customer, the Air Force. Regardless of the energy option chosen, Los Alamos would like to play a key role in its design and in the proof testing of the prototype unit.

Finally, I'd like to conclude my testimony with a brief description of compact reactor programs that potentially have both civil and defense applications. These are the space reactor programs.

There are two major initiatives in space power within the United States today. Both are directed by the triagency SP-100 organization. The first, the 10-to-1,000-kilowatt space nuclear power project, is well known to the committee. This program focuses its attention on a 100-kilowatt electric class reactor to power both civil and military missions in the early 1990's. Since the committee routinely hears testimony on this program, I will not dwell on it here.

The jet propulsion laboratory manages the project, since it has a strong civilian and commercial space component, and Los Alamos provides the nuclear technical management for JPL in the SP-100 project office.

The other major initiative within the SP-100 program is the multimegawatt project for space applications. The planning has just begun and, I am informed, is classified. While detailed classification guides have not yet been drawn, we have taken the route of being cautious in our testimony today, rather than risk exposure of classified information. Therefore, I have nothing further to report to you today, but certainly anticipate close interaction with you and your staff on this important national initiative in the near future.

I would like to thank the committee for the opportunity to testify here today and would be pleased to answer any questions the committee may have.

Thank you.

[The prepared statement of Dr. Boudreau follows:]

PREPARED STATEMENT OF DR. JAY E. BOUDREAU, LOS ALAMOS NATIONAL LABORATORY

HS&T TESTIMONY - 10 MIN

GOOD AFTERNOON MADAME CHAIRMAN, MEMBERS OF THE COMMITTEE, AND DISTINGUISHED COLLEAGUES. I HAVE BEEN ASKED TO BRIEF THE COMMITTEE TODAY ON LOS ALAMOS PROGRAM ACTIVITIES IN THE AREA OF COMPACT REACTORS FOR BOTH CIVILIAN AND DEFENSE APPLICATIONS. WHILE MANY OF OUR PROGRAM INITIATIVES ARE IN THE VERY EARLY STAGES AND SOME HAVE YET TO BE FULLY FUNDED, IT WAS FELT THAT THE COMMITTEE WOULD FIND INTEREST IN AND PERHAPS EVEN SOME ENTHUSIASM FOR THE PROMISE THAT THESE PROGRAMS APPEAR TO HOLD FOR THE FUTURE OF NUCLEAR POWER IN THE US. IF I MAY, I WOULD LIKE TO SUBMIT MY FULL TESTIMONY FOR THE RECORD, AND HIGHLIGHT THREE PARTS FOR THE COMMITTEE: (1) REACTORS FOR CIVILIAN USE, (2) REACTORS FOR DEFENSE USES, AND (3) REACTORS THAT MAY HAVE BOTH CIVILIAN AND DEFENSE USES.

FIRST, LET'S DISCUSS REACTORS FOR CIVIL USE. IN THE TWO DAYS OF TESTIMONY BEFORE THE COMMITTEE, A WIDE RANGE OF PROPOSALS FOR COMPACT OR MODULAR REACTOR TECHNOLOGIES WILL BE MADE. EACH CONCEPT HOLDS PROMISE FOR EXCITING BREAKTHROUGHS THAT MAY MAKE NEW ORDERS FOR NUCLEAR POWER IN THE US POSSIBLE AT SOME TIME IN THE FUTURE. THE PLUSES AND MINUSES OF EACH CONCEPT VARY, HOWEVER, AND IT IS DIFFICULT TO CHOOSE WHICH IS BEST WITHOUT HAVING ONE OR SEVERAL YARDSTICKS WITH WHICH TO MEASURE THEIR USE FOR VARIOUS APPLICATIONS. WITH SO MANY DIFFERENT CONCEPTS BEFORE US,

HS&T TESTIMONY - 10 MIN

GOOD AFTERNOON MADAME CHAIRMAN, MEMBERS OF THE COMMITTEE, AND DISTINGUISHED COLLEAGUES. I HAVE BEEN ASKED TO BRIEF THE COMMITTEE TODAY ON LOS ALAMOS PROGRAM ACTIVITIES IN THE AREA OF COMPACT REACTORS FOR BOTH CIVILIAN AND DEFENSE APPLICATIONS. WHILE MANY OF OUR PROGRAM INITIATIVES ARE IN THE VERY EARLY STAGES AND SOME HAVE YET TO BE FULLY FUNDED, IT WAS FELT THAT THE COMMITTEE WOULD FIND INTEREST IN AND PERHAPS EVEN SOME ENTHUSIASM FOR THE PROMISE THAT THESE PROGRAMS APPEAR TO HOLD FOR THE FUTURE OF NUCLEAR POWER IN THE US. IF I MAY, I WOULD LIKE TO SUBMIT MY FULL TESTIMONY FOR THE RECORD, AND HIGHLIGHT THREE PARTS FOR THE COMMITTEE: (1) REACTORS FOR CIVILIAN USE, (2) REACTORS FOR DEFENSE USES, AND (3) REACTORS THAT MAY HAVE BOTH CIVILIAN AND DEFENSE USES.

FIRST, LET'S DISCUSS REACTORS FOR CIVIL USE. IN THE TWO DAYS OF TESTIMONY BEFORE THE COMMITTEE, A WIDE RANGE OF PROPOSALS FOR COMPACT OR MODULAR REACTOR TECHNOLOGIES WILL BE MADE. EACH CONCEPT HOLDS PROMISE FOR EXCITING BREAKTHROUGHS THAT MAY MAKE NEW ORDERS FOR NUCLEAR POWER IN THE US POSSIBLE AT SOME TIME IN THE FUTURE. THE PLUSES AND MINUSES OF EACH CONCEPT VARY, HOWEVER, AND IT IS DIFFICULT TO CHOOSE WHICH IS BEST WITHOUT HAVING ONE OR SEVERAL YARDSTICKS WITH WHICH TO MEASURE THEIR USE FOR VARIOUS APPLICATIONS. WITH SO MANY DIFFERENT CONCEPTS BEFORE US, would it not be desirable to begin to centralize our review and to measure the performance and value of each reactor concept against a commonly agreed upon set or sets of measures? At Los Alamos, we are working with the DOE in two important areas so that such sets of measures can be identified. While some of the work is ongoing, some is just beginning, but we feel both areas hold great promise.

Our ongoing efforts involve work in cooperation with the nuclear industry to evaluate and improve upon the design of their modular breeder concepts. As DOE's lead lab for the advanced carbide fuel program, for example, we and GE are cooperatively exploring the inherent safety features of GE's design, its reliability, performance, and so on and are searching for ways in which use of the carbide fuel might give us more flexibility to achieve those ends.

We believe that our cooperative effort with the General Electric Company is particularly beneficial to both parties since it capitalizes on the unique talents of each organization. General Electric brings great expertise in reactor design and Los Alamos is uniquely qualified in the areas of safety and licensing of advanced reactor concepts, as evidenced in its lead role for the Nuclear Regulatory Commission in technical assistance on Clinch River licensing.

LOS ALAMOS WILL DEVELOP A MIXED CARBIDE CORE DESIGNED TO MEET THE MODULAR REACTOR REQUIREMENTS AND OPTIMIZED FOR SAFETY, PERFORMANCE, AND ECONOMY. THIS CARBIDE CORE DESIGN WILL BE AN OPTION TO THE REFERENCE OXIDE CORE DESIGN AND WILL BE REVIEWED PERIODICALLY BY GE TO ESTABLISHED CRITERIA FOR ITS ADVANTAGES. THE CRITERIA WILL BE ESTABLISHED JOINTLY BY GE AND LOS ALAMOS.

LOS ALAMOS WILL DELINEATE AN APPROACH TO SAFETY AND LICENSING THAT CAPITALIZES UPON THE UNIQUE DESIGN FEATURES OF THE MODULAR REACTOR, ASSURING COST-EFFECTIVE WAYS OF REDUCING THE LIKELIHOOD OF HAZARDS AND INJURY TO THE PUBLIC AND FINANCIAL RISK TO THE PLANT OWNERS. BOTH CARBIDE AND OXIDE CORE DESIGNS WILL BE CONSIDERED IN THESE EFFORTS.

IF WE SUCCEED IN OUR INITIATIVE WITH GE, ONE EXAMPLE OF THE KIND OF BENEFITS THAT MIGHT BE REALIZED WITH ADVANCED TECHNOLOGY AND DESIGN WILL BE BETTER QUANTIFIED.

THE OTHER LOS ALAMOS PROGRAM THAT COULD IMPACT THE FUTURE OF COMMERCIAL NUCLEAR POWER IN THE US AND IS ALSO SPONSORED BY THE DOE IS A "MARKET SURVEY" OF A VERY DIFFERENT KIND. THIS SURVEY DOES NOT SEEK A HOME FOR AN EXISTING PRODUCT. RATHER, IT SEEKS A CUSTOMER, IDENTIFIES HIS NEEDS, AND THEN ALLOWS FOR A DETERMINATION OF THE BEST PRODUCT TO MEET THOSE NEEDS. SPECIFICALLY, WE HAVE FORMED A SMALL STEERING GROUP, EXTERNAL to Los Alamos, to begin the process. Key members of this steering committee include the Vice President and General Manager for Kaiser Aluminum, representatives from Wall Street, and the past chairman of the AEC. For the record, they are:

James W. Zigler, Senior Vice President
Dillon, Read & Co., Inc.
Project Financing

John D. Sanders, Vice President
Wachtel and Co., Inc.
Project Financing

Dr. Dixy Lee Ray
Consultant

Howard M. Nelson
Vice President and General Manager
Kaiser Aluminum & Chemical Corporation

Martin L. Lyons, Senior Vice President
E. F. Hutton Company Inc.
Utility Financing

Fernando B. Sotelino
Vice President and Manager, Specialized Finance Group
Crocker Citizens Bank
Project Financing

The Board will consider electricity generation needs on a very specific basis rather than through the many past studies conducted for the traditional electricity reliability regions. If specific electricity needs are identified, our study will seek to identify the conditions under which any energy supply option could be purchased. We hope to identify such design goals as: power range, reliability, cost, lead time, etc. Once these targets are identified , the DOE will have a set of goals to shoot for and reactor designs of all sorts can be screened against the goals. If technology development needs exist, and if the investment risk is too high for industry to shoulder alone, the Department has the option to structure its R&D program priorities accordingly. The industry has the option to proceed with its involvement in the program depending on its perception of investment risk. Let us discuss the program in slightly more detail.

We expect to have results from our market survey on two time scales. The first results are anticipated within the next six months. They include

(1) IDENTIFICATION OF THE POTENTIAL MARKET BY GEOGRAPHIC AREA, (2) POWERAND CAPITAL COST OBJECTIVES, (3) SPECIFIC LEAD TIME REQUIREMENTS, (4) IDENTIFICATION OF POTENTIAL CUSTOMERS, AND (5) UNIT SIZE. BY JULY WE EXPECT OUR MARKET SURVEY TO IDENTIFY THE FACTORS THAT GOVERN DECISIONS TO BUY OR BUILD POWER PLANTS. THESE FACTORS INCLUDE COSTS, PROTECTION AGAINST GOVERNMENTAL POLICY CHANGES, CUSTOMER AND DECISION MAKER BIAS, FUEL CYCLE CONCERNS, REGULATORY REFORM, REGIONAL CONSIDERATIONS, AND THE AVAILABILITY OF WHOLESALE SUPPLY. ONCE WE HAVE ESTIMATED THE NUMBER, TYPE, AND SIZE OF FUTURE GENERATING PLANTS BY GEOGRAPHIC REGIONS AND HAVE ALSO DETERMINED THE BUYER'S REQUIREMENTS FOR BUILDING A NEW GENERATION PLANT, WE WILL EXAMINE THE CURRENT AND ANTICIPATED REGULATORY, INSTITUTIONAL, LEGAL, SOCIAL, AND POLITICAL FACTORS THAT WILL INFLUENCE THE BUYER'S DECISION PROCESS. THE RESULT OF ALL OF THIS WORK WILL BE SUBMITTED IN DRAFT FORM TO THE DEPARTMENT OF ENERGY IN JULY OF 1984.

A FINAL STEP IN OUR MARKET SURVEY WILL BE TO DETERMINE THE PORTION OF THE DEFINED MARKET THAT MIGHT BE CAPTURED BY THE BREEDER.

BEFORE GOING ON TO DISCUSS REACTORS FOR DEFENSE, I WOULD LIKE TO HIGHLIGHT THAT REGARDLESS OF THE DETAILS OF DESIGN, ALL OF THE REACTORS WE ARE DISCUSSING DURING THESE TWO DAYS HAVE SOME FEATURES THAT HAVE BEEN THE CONCERNS OF THE US NUCLEAR PROGRAM SINCE THE BEGINNING. THEY ALL STRIVE FOR INHERENTLY SAFE DESIGNS--DESIGNS THAT ARE AS NEARLY "WALK AWAY

SAFE" AS POSSIBLE. THEY ALL STRIVE TO DRAMATICALLY REDUCE CAPITAL COSTS. THEY ALL SEEK DRAMATIC REDUCTIONS IN CONSTRUCTION TIME, AND SO ON. IS IT IS POSSIBLE THAT THE BILLIONS OF DOLLARS PREVIOUSLY INVESTED IN REACTOR TECHNOLOGY CAN NOW BE EXPLOITED TO BENEFIT THE NEW REACTOR INITIATIVES? CAN WE DRAW ON THE PEOPLE, INSTITUTIONS, KNOWLEDGE, AND PRIVATE AND GOVERNMENT COMMITMENT TO THE BREEDER PROGRAM TO REESTABLISH NUCLEAR POWER IN THE US? I PERSONALLY SEE NOTHING TO PREVENT IT IF THAT IS WHAT THE COUNTRY WISHES TO DO.

NOW LET US SWITCH TO THE TOPIC OF REACTORS FOR APPLICATION TO PURELY DEFENSE NEEDS. THERE ARE TWO PROGRAMS HERE THAT MERIT YOUR ATTENTION. THE FIRST IS THE SO-CALLED DEFENSE TERRESTRIAL PROGRAM, AND THE SECOND IS REACTORS FOR USE IN THE NORTH WARNING SYSTEM.

A NUMBER OF STUDIES HAVE BEEN CONDUCTED FOR THE AIR FORCE BY LOS ALAMOS TO EVALUATE THE DESIRABILITY OF PROVIDING AN INDEPENDENT AND RELIABLE SOURCE OF ELECTRICITY FOR KEY AIR FORCE BASES. UPON REVIEW OF THESE REPORTS AND OTHERS, THE AIR FORCE HAS DETERMINED THAT A MORE CAREFUL TECHNICAL REVIEW OF ENERGY SUPPLY OPTIONS FOR THESE KEY BASES IS DESIRABLE. LOS ALAMOS HAS BEEN ASKED TO SUBMIT A PROGRAM PLAN THROUGH THE DEPARTMENT OF ENERGY THAT WOULD ENABLE CONSTRUCTION OF A PROTOTYPE REACTOR UNIT WITHIN THE NEXT FIVE YEARS. SHOULD THE PROTOTYPE OPERATION PROVE SUCCESSFUL, THE AIR FORCE COULD THEN DECIDE WHETHER TO MORE WIDELY

DEPLOY SUCH UNITS AT OTHER BASES. THE LABORATORY HAS BEEN ASKED TO MANAGE THE PROGRAM AND TO SELECT BETWEEN DESIGN PROPOSALS SUBMITTED BY INDUSTRIAL CONTRACTORS IN RESPONSE TO FORMAL REQUEST-FOR-PROPOSALS IN THE MONTH OF MARCH.

WHILE WE ARE VERY EXCITED ABOUT THE PROSPECTS FOR THE DEFENSE TERRESTRIAL REACTOR PROGRAM, ANOTHER NEW PROGRAM AFFORDS CHALLENGES OF A DIFFERENT KIND. THE AIR FORCE HAS AN ONGOING PROGRAM TO EVALUATE PROGRAM NEEDS TO REPLACE THE DEFENSE EARLY WARNING (DEWLINE) SYSTEM. THE DEWLINE WAS DESIGNED TO PROVIDE SURVEILLANCE AND WARNING AGAINST SOVIET ATTACK. THE NEW NORTH WARNING SYSTEM PROGRAM WILL, AS PART OF ITS CHARTER, SEEK TO IMPROVE CERTAIN ASPECTS OF THE POWER SUPPLY FOR RADAR SYSTEMS THAT CAN PERFORM TO MEET BALLISTIC MISSILE DEFENSE NEEDS.

THE POWER SUPPLY FOR THE NORTH WARNING SYSTEM WILL NEED TO PROVIDE 5 TO 40 KWE OF CONTINUOUS AND RELIABLE ELECTRICITY IN A COMPLETELY UNATTENDED MODE OF OPERATION. OUR TARGET AT THIS TIME IS 18 MONTHS OF UNATTENDED OPERATION. POWER SUPPLIES ARE LOCATED IN REMOTE PORTIONS OF THE NORTHERN HEMISPHERE THAT ARE DIFFICULT TO ACCESS AND THAT OFFER A HOSTILE ENVIRONMENT FOR MAINTENANCE, REPAIR, REFUELING, AND IN GENERAL, MANNED INTERVENTION. A NUMBER OF POWER SUPPLY OPTIONS ARE UNDER REVIEW. THESE INCLUDE REACTORS, FUEL CELLS, DIESEL POWER SUPPLIES, AND OTHERS. THE PROGRAM AT LOS ALAMOS IS IN ITS EARLY STAGES AND WE ARE PRESENTLY

EVALUATING THE DIFFERENT ENERGY SUPPLY OPTIONS AGAINST A SET OF REQUIREMENTS BEING DEFINED BY THE AIR FORCE. REGARDLESS OF THE ENERGY OPTION CHOSEN, LOS ALAMOS WOULD LIKE TO PLAY A KEY ROLE IN ITS DESIGN AND IN THE PROOF-TESTING OF THE PROTOTYPE UNIT.

FINALLY, I WOULD LIKE TO CONCLUDE MY TESTIMONY WITH A BRIEF DESCRIPTION OF COMPACT REACTOR PROGRAMS THAT POTENTIALLY HAVE BOTH CIVIL AND DEFENSE APPLICATIONS. THESE ARE THE SPACE REACTOR PROGRAMS.

THERE ARE TWO MAJOR INITIATIVES IN SPACE POWER WITHIN THE US TO DATE. BOTH ARE DIRECTED BY THE TRIAGENCY SP-100 ORGANIZATION. THE FIRST, THE 10-1,000 KILOWATT SPACE NUCLEAR POWER PROJECT, IS WELL KNOWN TO THE COMMITTEE. THIS PROGRAM FOCUSES ITS ATTENTION ON A 100-KWE CLASS REACTOR TO POWER BOTH CIVIL AND MILITARY MISSIONS OF THE EARLY 1990S. THE PROGRAM IS WELL UNDERWAY AND TARGETS FOR DECISIONS IN JULY OF 1985 ON WHETHER TO GO FORWARD WITH THE GROUND ENGINEERING AND FLIGHT QUALIFICATION PHASE FOR SUCH A CLASS OF REACTOR SYSTEMS. SINCE THE COMMITTEE ROUTINELY HEARS TESTIMONY ON THIS PROGRAM, I WILL NOT DWELL ON IT HERE. THE JET PROPULSION LABORATORY MANAGES THE 10-1,000 KILLOWATT PROJECT SINCE IT HAS A STRONG CIVILIAN AND COMMERCIAL SPACE COMPONENT, AND LOS ALAMOS PROVIDES THE NUCLEAR TECHNICAL MANAGEMENT FOR JPL IN THE SP-100 PROJECT OFFICE.

THE OTHER MAJOR INITIATIVE WITHIN THE SP-100 PROGRAM IS THE MULTIMEGAWATT PROJECT FOR SPACE APPLICATIONS. THE PLANNING HAS JUST BEGUN AND IS CLASSIFIED. THEREFORE, I HAVE NOTHING FURTHER TO REPORT FOR YOU TODAY BUT CERTAINLY ANTICIPATE CLOSE COMMUNICATION WITH YOUR STAFF ON THIS IMPORTANT NATIONAL INITIATIVE IN THE NEAR FUTURE.

I WOULD LIKE TO THANK THE COMMITTEE FOR THE OPPORTUNITY TO TESTIFY HERE TODAY AND WOULD BE PLEASED TO ANSWER ANY QUESTIONS THE COMMITTEE MAY HAVE. THANK YOU.

Mrs. Lloyd. Well, thank you very much, Dr. Boudreau.

Dr. Wright, would you please join Dr. Boudreau at the panel, also?

Dr. Wright, the present SP-100 budget through fiscal year 1985 does not seem adequate to support an orderly transition into an energy development activity by 1986. In addition, the committee wants to insure that a thorough evaluation of technology and safety issues takes place before a space power system concept is selected for further development. If additional funds were provided in fiscal year 1985, could they be used for such purposes as well as perhaps support more intensive mission definition efforts?

Dr. Wright. Let me start by reviewing very briefly what the objective of the current phase is. That's to identify a concept and to prove its feasibility of operation, and also to prove that it can feasibly meet the various safety criteria, not to complete a rigorous definition of its properties.

We had envisioned that fiscal 1986 would, in fact, be a year of transition and that we would not be able to step from the current program instantly into a full-fledged engineering development program. It would certainly be possible to start some of those activities earlier, but, as I said, the current budget was not structured to support that nor was the current memorandum of agreement between the three agencies.

Mrs. Lloyd. If the funds were provided for the program, could they be used for thorough evaluation of technology and safety, to speed up the mission?

Dr. Wright. I've yet to meet a manager of a program would say honestly that he could not use more funds. As I said——

Mrs. Lloyd. Could you use them wisely?

Dr. Wright. Yes; I think that's the question.

As I said, within the current objectives, we don't need any additional funds. However, if additional funds were provided, they could probably help to ease the transition from the technology assessment and advancement phase that we are in now to a more full-fledged development program.

The areas that you have suggested seem to me as reasonable ones that would have to be enhanced in any case in 1986. It could certainly be possible to enhance some of those wisely in 1985.

Mrs. Lloyd. Would you describe, just for the record, the nature and the scope of the safety-related activities that are within the SP-100 program?

Dr. Wright. Certainly.

I think we have to understand a little bit, first, about the environment that we're talking about for the safety problem, and then think a little bit about the safety activities in relationship to the long-term run of the program.

We have a very unique challenge to deal with. We've heard concepts for inherently safe reactors today, but those are principally terrestrial, fixed-location kinds of reactors.

We have some pluses and some minuses in the safety area we have to deal with. The first is that we are very concerned that we have to endure the shuttle launch environment. We have to have a portable reactor that we could put into the shuttle and get into space safely. We have some advantages there. We could put it up before it had built up any radioactive products, but it is still a concern. It is a stressing environment compared to other activities.

On the other hand, some aspects of it lend themselves to a more inherently safe system. Operating deep in space, the impact of any accidents or breakdown in the equipment could result in much less impact on the surrounding environment. The danger, the hazards of such an accident are less.

But we have to understand this environment very carefully and its impact on our concepts that we're trying to take forth.

We have to have a phased approached to the safety issues. Specifically, there are two decision points that we have to look toward, where we may face very serious concerns, both from within the Government and from the public. The last one, the obvious one, is once we're ready to fly a system, will we be allowed to fly it? I think that will only happen if we have a very detailed, very rigorous proof through experiment, through analysis, that the systems we're proposed to do and the operating concepts that we're going to implement do, indeed, meet the safety criteria that have been laid down.

So about the time that we're ready to fly, say early in the 1990's, we must have a very detailed proof that what we are going to do is safe.

The next decision point, coming backward in time, is the one that we face at the end of 1985, 1986. Can we take a specific concept forward into engineering development with some reasonable assurance that we will be able to meet safety requirements? We need not have everything nailed down at that point, but we certainly need to understand the basic environment and whether the concepts that we're going to look at can feasibly meet reasonable safety requirements.

So our job right now is to do three things. We are conducting analyses as part of the concept design work to understand how the reactors behave under certain conditions. We are beginning to more clearly define safety criteria and to understand public concerns, and, finally, we're beginning to interact with the external independent safety review organizations that you know exist, such as the one within the safety and quality assurance organization within the Department of Energy and the INS rep relating to actual approval for flight. So those are the three activities we're carrying on at this point.

Now in order to accomplish this, we have tasked Los Alamos to conduct a number of safety analyses for the program, and we are just about to restructure some of the management activities relating to safety in order to give pieces of it higher visibility within the program. That will happen in the next week or two.

I'm sorry for the drawn-out answer, but I think it deserved one.

Mrs. LLOYD. Thank you very much.

Dr. Boudreau, you mentioned the civilian and the defense reactor design. What are the generic features of the compact reactor designs under study at Los Alamos that are attractive from a civilian application perspective?

Dr. BOUDREAU. The attractive features are many of those discussed during the previous 2 days. Our study only differs in that it tries to quantify these measures a little more precisely, so that we'll have yardsticks to measure the various concepts against one another.

Perhaps a moment or two more of detail of what's in that study would be appropriate for the record.

Mrs. **Lloyd**. Please proceed.

Dr. **Boudreau**. We intend in the next 6 months to identify the potential market by geographic area in the United States; the power and capital cost objectives will be quantified; specific lead time requirements will be identified; and the identification of the specific customers in addition to the unit size.

By July, we expect our market survey to identify the factors that govern decisions to buy or build powerplants. These factors include costs, protection against Government policy changes, customer indecision, maker bias, fuel cycle concerns, regulatory reform, regional considerations, and the availability of wholesale supply. Once we've estimated the number, type, and size of future generating plants by geographic region, and have also determined the buyers' requirements for building a new generation plant, we will then examine the current and anticipated regulatory, institutional, legal, social, and political factors that will influence the buyers' decision process.

We hope that through this rather intense, but exhaustive, look at all of these issues to come up with some specifics that will provide all of the decisionmakers a basis to compare the concepts and targets for the future designs of advanced concepts.

Mrs. **Lloyd**. Does your steering committee support your market study?

Dr. **Boudreau**. Yes; it does.

Mrs. **Lloyd**. Are they working under contract to DOE?

Dr. **Boudreau**. No; they're working totally on their own initiative.

Mrs. **Lloyd**. How does this committee function? Does it just meet periodically?

Dr. **Boudreau**. Yes, Madam; it meets approximately once a month and is staffed by Los Alamos under contract to DOE to answer the various questions. The committee then discusses the matter with itself, financial people from Wall Street, discuss the formation of moneys with the potential customer, and new questions will come back to Los Alamos for resolution.

Mrs. **Lloyd**. What is the source of funding for the steering committee?

Dr. **Boudreau**. The steering committee, as I said, is totally independent. It's a volunteer activity of their own.

Mrs. **Lloyd**. Who pays their airfare and this sort of thing?

Dr. **Boudreau**. Their parent companies.

Mrs. **Lloyd**. Their parent companies?

Dr. **Boudreau**. Yes.

Mrs. **Lloyd**. Will there be a report on the funding of your market study that will be available to this committee?

Dr. **Boudreau**. Yes, Madam, I believe so.

Mrs. **Lloyd**. What is the split between the defense work and the civilian program for your compact work, reactor work?

Dr. **Boudreau**. Do you mean the split in Los Alamos funding?

Mrs. **Lloyd**. That's correct.

Dr. BOUDREAU. As I mentioned in my testimony, the new defense reactors are in the very early phases of development. Therefore, we anticipate for the defense terrestrial reactor program approximately $2 million for fiscal year 1984. In the North Warning System we are operating on pilot funds from the Air Force Engineering Services Center at Tindall Air Force Base in the amount of approximately $200,000.

The total nuclear program funding at Los Alamos is approximately $54 million in fiscal year 1984. So, therefore, at this point the ratio is approximately a little over $2 million.

Mrs. LLOYD. How is DOE involved in your market study?

Dr. BOUDREAU. DOE sponsors the study that we are conducting. They will, I believe, contribute approximately $2 million to that study this year, $1 million of which—or a little over $1.5 million of which, I beg your pardon—will be exterior to Los Alamos and——

Mrs. LLOYD. Are you under any direction from DOE?

Dr. BOUDREAU. We work very closely with them, yes. We recommended that such an approach be taken. We're working in direct cooperation with them.

Mrs. LLOYD. Thank you.

Staff has a question they'd like for me to ask you, Dr. Wright.

When can this committee expect definitive information on the mission requirements for the SP-100 system?

Dr. WRIGHT. Very much like the safety activities, I think we can see that as a phased process. Again, let me start at the end of the program and work backward.

By the time we have completed the engineering development and ground tests and we are ready to embark upon first flight applications and first tests in space, clearly a single, definitive, first mission must be identified. We must know precisely the space system that it's going on. We must have precise schedules and funding. So it has to be nailed down thoroughly at that point.

The decision that we have to make at the end of 1985, as to which, if any, of these concepts to take into engineering development, we can have probably a somewhat more generic understanding of the mission.

I would expect that by the end of 1985 or 1986 that we will be able to see the three classes of missions that I identified earlier much more clearly drawn with clear limits on performance and a very certain understanding as to what users would be interested. They will have to voice their interest, and we should also be very certain at that time what added capabilities and benefits space nuclear power brings to these missions. If we are unable to produce that at that time, we should not, in fact, proceed with engineering development.

I think what we should be able to see in the next few months is a gradual clarification of those three principal missions and a better understanding, a better numerical understanding, of what space nuclear power might bring to communications, to radar surveillance, and to the space station.

Mrs. LLOYD. Thank you very much, gentlemen. We will have questions that we will submit in writing from Mr. Young who was unable to get here in time, if you would respond to these questions.

Mrs. LLOYD. Are there questions from the staff?

Please proceed.

Mr. CLEMENT. Thank you, Madam Chairman.

Dr. Boudreau, hearing your testimony about your market survey, it sounds remarkably like what we were taught in business school; it was product development surveys. We've heard a number of things so far about the administration feeling that private industry should take over wherever possible, and this certainly sounds like a potential candidate.

Would you provide the committee a copy of the directive which initiated this activity, a listing of the amount of funds being utilized and the source of that funding, the qualifications of those personnel making this market survey, the extent of the interface with the steering group you mentioned, any known past examples of similar activity, and any information that would justify to the committee Los Alamos undertaking this activity?

Dr. BOUDREAU. I'll be happy to.

Mr. CLEMENT. Thank you.

Dr. Wright, I sat here listening to your testimony, and I think most people are familiar with the fact that the Department of Defense has a hard time calling a spade a spade. In fact, they call it a tool-entrenching individual.

But it struck me that we seem to be attempting to invent a mount steel for tire rubber vehicular—otherwise known as the wheel.

Let me ask you: you listed three possible applications for space nuclear reactor power sources, including a growth space station. Can you tell us within one order of magnitude what amount of power you anticipate for the space station as the initial configuration?

Dr. WRIGHT. For the initial configuration?

Mr. CLEMENT. Yes.

Dr. WRIGHT. As envisioned with solar cells?

Mr. CLEMENT. Well, what will the power requirement be for the initial configuration that NASA is now talking about?

Dr. WRIGHT. I'm not certain what it is. I believe it's somewhat short of 100 kilowatts for the initial configuration.

Mr. CLEMENT. Didn't we in the original SNAP program have a unit that was tested for almost a year that produced a megawatt?

Dr. WRIGHT. There were a variety of reactors tested. There was one that produced almost a megawatt of thermal power.

The problem is that, if you take the SNAP technology and scale it to the power requirements for the space station or any of these other applications, you will find that the size and weight of that technology is prohibitive. It is not compatible with shuttle operations.

Mr. CLEMENT. Madam Chairman, we have a couple of other questions. Could we submit them for the record?

Mrs. LLOYD. Without objection.

We do thank you for your testimony, for all of you that participated in our hearings today. You've spent a lot of time here. We thank you for your input as well as your patience. Thank you.

The subcommittee stands adjourned.

[Whereupon, at 4:20 p.m., the subcommittee recessed, to reconvene at the call of the Chair.]

1985 DEPARTMENT OF ENERGY AUTHORIZATION

THURSDAY, FEBRUARY 9, 1984

House of Representatives,
Committee on Science and Technology,
Subcommittee on Energy Research and Production,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9 a.m., in room 2318, Rayburn House Office Building, Hon. Marilyn Lloyd (chairwoman of the subcommittee) presiding.

Present: Representatives Lloyd, Valentine, and Walker.

Staff present: Jack Dugan, staff director; Louis Ventre, Jr., counsel; William T. Harvey, minority energy coordinator; and David Clement, minority counsel.

Mrs. Lloyd. The Subcommittee on Energy Research and Production will come to order.

Good morning, ladies and gentlemen. The rules of the committee require that the subcommittee grant permission for recording devices to be used by the media or the public in our proceedings. I, therefore, request unanimous consent that we permit our hearings today to be recorded by audio or visual means. Without objection, so ordered.

Today, we will be receiving testimony on the Department of Energy's commercial nuclear waste research and development program, the nuclear waste fund program, the remedial action program, the West Valley demonstration program, and the light water reactor extended burnup program.

Our witnesses this morning are from outside of the Department of Energy and include the Honorable James F. McNulty, Jr., a colleague and member representing the Fifth District of Arizona; Mr. Donald Mausshardt with the staff of the Nuclear Regulatory Commission; Mr. Sherwood Smith representing the Edison Electric Institute; Mr. Leo Duffy from the Westinghouse Electric Corp.; and Mr. Warren Chernock from the Combustion Engineering Co.

The subcommittee hopes to receive testimony from these witnesses on the timing, direction, and adequacy of all of the subject programs. We are principally interested in the witnesses' criticisms of these programs as well as the reasons for their recommending our continued support.

This afternoon, beginning at 1 p.m., we will hear the Department of Energy's explanation of their budget request for these programs. Dr. Frank Coffman and Mr. Michael Lawrence will represent the Department. We expect to be able to question them on the concerns raised by the witnesses this morning as well as topics of specific interest to the subcommittee.

The Department of Energy recently published a draft of volume 1 of the mission plan for the nuclear waste fund activities which sets forth the Department's major assumptions of their approach to the conduct of the nuclear waste fund program. As many of you may know, the idea for the mission plan originated in this subcommittee with Congressman Lundine from New York. Although this first volume of this mission plan does not satisfy the requirements of the act, it does set forth a number of policy issues which must be addressed in Congress. Of primary concern to this subcommittee is the failure of the Department to comply with the time schedule set forth in the act. We shall be interested in the witnesses' perception of this problem. Additionally, we want to insure that the planning for the committee's own test and evaluation facility will be consistent with the intent of the law.

The subcommittee will also investigate whether the West Valley project is being conducted consistent with the West Valley Demonstration Project Act. It has come to our attention that certain remedial actions at the site might more properly be the responsibility of the State of New York rather than the Federal Government under this act. We may wish to explore this issue in further detail with the Westinghouse witness this morning and the DOE this afternoon.

Another issue for the committee is the progress being made on the spent fuel storage research and development program. Hopefully, our EEI witness will address this issue from the perspective of a participant in the program. I have considerable interest in this program since my utility, the Tennessee Valley Authority is very actively engaged in this and other complementary activities. I have a paper from a TVA employee on this subject which I would like to include in the record at the end of Mr. Smith's testimony and, without objection, it is so ordered.

Finally, the subcommittee will want to investigate the probable funding needs for the light water reactor extended burnup program. The subcommittee and the committee have been committed to this program in prior years, and wish to see it carried to completion. The benefit-to-cost ratio of this program is so large that it would not be a rational or prudent decision to prematurely terminate it.

Before we begin, I was going to ask if the subcommittee's ranking Republican member, the gentleman from Pennsylvania would like to deliver an opening remark. He is not here at this time, but I do understand that Mr. Winn has a statement for the record, and, without objection, it will be inserted in the record at this time.

[The prepared statement of Mr. Winn follows:]

PREPARED STATEMENT OF HON. LARRY WINN, JR.

Thank you, Madam Chairman, for the opportunity to welcome our witnesses today. We look forward to hearing about the progress being made on the management of spent nuclear fuel and nuclear waste.

A relatively small amount of total waste management activity will be funded from the federal budget. However, it is very important that we evaluate that program, particularly in light of the support it will give to the much larger nuclear waste program which has been implemented by the Nuclear Waste Policy Act of

1982. In the latter case the funding will be obtained from the nuclear utilities at a 1-mill per kilowatt hour rate.

A great concern I have relative to the nuclear waste fund is the tendency to spend all of what we can get, whether it is necessary or not. Certainly, the Department of Energy is responsible to the industry for intelligent disbursement of funds for a meaningful nuclear waste management program. I am reminded of Parkinson's Law which states that "expenses rise to meet revenues".

In our strong support for the Nuclear Waste Policy Act we were all aware of the responsibility for the safe storage of these spent materials. A schedule was provided in the Act for timely design, construction, and operation of storage facilities. It is hoped that, if this schedule cannot be adhered to in the letter and spirit of the Act, this Committee will be advised formally by the Department of Energy at a very early time. We would need to know of the inability to perform as requested, the reasons involved, and the dates—which do appear to be appropriate.

Madam Chairman, I am sure that our witnesses will provide very beneficial information to this subcommittee today.

Thank you.

Mrs. LLOYD. We are very fortunate to have so many talented and dedicated members on this subcommittee, and at the top of the list I would have to put the name of my friend and my colleague, Mr. Tim Valentine who so ably represents his district and works so hard on this committee. Mr. Valentine is going to chair this committee at this time.

Mr. VALENTINE. The first witness on our list is my good friend and veteran first-termer, Mr. Jim McNulty. Jim, we are happy to have you here. Your entire written statement will be made a part of the record and you just proceed in any way that you deem appropriate. We are ready for you.

STATEMENT OF HON. JAMES F. McNULTY, JR., A REPRESENTATIVE IN CONGRESS FROM THE STATE OF ARIZONA

Mr. McNULTY. Good morning, Mr. Chairman, my good friend from Carolina. It is most agreeable for me to be here with you this morning. I am grateful to Chairwoman Lloyd and to have the opportunity to testify this morning on a subject of national nuclear waste disposal. It is a matter of enormous importance to us all, in Arizona, of course, because of the construction of a large nuclear generating plant west of Phoenix.

My testimony, though, is going to address a critical element in the overall high-level radioactive waste disposal program, and that element is the material that is going to be used in fashioning the canisters for the underground burial of waste.

I not only confess, but I embrace the idea that a substantial parochial interest has a lot to do with my being here this morning. Perhaps two-thirds of the domestic production of copper in American comes from Arizona's Fifth Congressional District, and at a time when that industry is in substantial peril. However, I think that I can do so in clear conscience for the reasons that I am going to enumerate.

Under the Nuclear Waste Policy Act of 1982, the Department of Energy is supposed to develop two national repositories for high-level waste that will be generated at our Nation's nuclear powerplants. We have 88 of them in the country now. The sites will employ a system known as multiple barrier containment and will call upon the containment canister and the surrounding geology to prevent radioactivity from entering the biosphere.

The decisions eventually reached by DOE and Congress on details of that program are decisions we are all going to have to live with for many generations to come.

With the importance of that in mind, we ought to consider the approach taken by a government which has already gone through a process like this, the Government of Sweden. In a study of radioactive waste disposal ending last year, Sweden sought unsuccessfully to find a method of waste disposal that was absolutely, permanently safe. When such a system couldn't be found, Sweden decided to take a look at a system which its study indicated might be safe for hundreds of thousands, perhaps even a million, years. That system would involve the use of copper canisters surrounded by clay and placed in crystalline rock. The conclusions reached in this preliminary study were confirmed by a study done by the National Research Council of our own National Academy of Sciences.

By comparison, the objective of the study underway in the United States today appears to be development of a system that can provide a reasonable assurance that the public and the environment will be adequately protected. The Nuclear Waste Policy Act doesn't require anything more substantial and that requirement, which I would consider a minimum requirement, seems to be the aim of the DOE today.

DOE is researching the use of stainless steel canisters placed in salt formations. I know a little bit about that having visited the Savannah River test station and the pilot project there built by Dupont, in which a material something like glass is to be inserted into these stainless steel canisters and then a plug is to be inserted into the neck of that thing and subjected to enormous electric charge which welds the plug in place.

We think a canister in such an environment would have a life expectancy between 300 and 1,000 years, and after that, the canister would fail, and radiation would leak into the salt formation. From that point on, we would rely on the stability of the geology to prevent radioactivity from reaching the biosphere.

The fundamental difference between the Swedish approach and the American approach has concerned the canister material. The Swedes studied copper and found it would last hundreds of thousands of years, placed in the proper environment. The United States is studying stainless steel and has virtually conceded that it would be good for a period of some 300 to 1,000 years under the optimum environment.

Clearly, copper must pose some other problems or it would have been under study as well, but from what I am able to discern, those problems are not insurmountable.

Until recently, copper was considered a difficult metal to weld, but the Swedish Government says that a process known as hot isostatic pressing—which I hope I will not be required to explain—and other studies have determined that the process of electron beam welding could allow copper to be welded properly.

Mr. VALENTINE. Mr. McNulty, I had that on my list of questions to ask you, but——

Mr. McNULTY. Thank goodness I got the caveat in before I heard the question.

Questions have also been raised concerning copper's resistence to corrosion. Energy Secretary Donald Hodel has stated that copper is less resistant to corrosion that other candidate materials. In a salt environment, research has shown that is true, but research in a crystalline rock environment such as that used by the Swedes, the copper has proven its durability.

On two occasions, the Department of Energy referred to copper as a "critical natural resource" in explaining why it wasn't being studied. If the word critical means the metal is in short supply or expensive, I would simply note that there is something like three-quarters of a million metric tons surplus copper in the world today, and that the world copper price of about 65 cents per pound is at the lowest point, in real terms, in the 20th century. If critical means the metal is vital to the Nation's security, then I would have to wonder why we haven't purchased a single pound of copper for the national strategic stockpile even though that stockpile today is 29,000 tons—or 3 percent of the national security level determined by FEMA.

Copper has not been studied, it is said, because it is too expensive, but the use of stainless steel in the overall program would only be less expensive than copper by a figure of about 10 percent. I think enough evidence exists that copper may be significantly safer than stainless steel under proper circumstances. If we can prove that to be the case, through research, then it may very well follow that some additional cost is worthwhile. We should not take chances with long-term radioactive waste disposal. To do so is to put future generations at risk.

It is true, beyond any doubt, that the domestic copper industry in America would find a program like this significant, and conceivably a valuable new market, but we are some time away from that. For an industry that is operating at barely half its level of 5 years ago, the adoption of copper as a material for nuclear waste disposal could, in 6 or 8 years, mean a new market for as much as 2 million metric tons of copper which is more than the biggest single year production in the last 25 years.

Secretary Hodel, I am pleased to tell you, testified just Tuesday of this week before the Subcommittee on Energy and Environment of the House Interior Committee. I am not a member of the subcommittee though I am a member of the full committee, and I have worked very closely with the chairman of that committee, Mr. Udall, on this issue.

The Secretary indicated that DOE will now begin to study the use of copper in the canister program, and that is an important step forward. I wanted to assure this panel that I would be more than willing to work toward the adoption of any legislation if it is indeed necessary to accommodate the expanded study.

Once the decision is finally made on the material in these canisters, we are going to have to live with the results of that decision for a long time, many years and many lives, so this deserves very careful consideration from the Congress.

With the subcommittee's approval, Mr. Chairman, I would like to submit for the record a background document entitled, "A Perspective on Potential Uses for Copper in High-Level Radioactive Waste Disposal," prepared by Arizona's copper mining supply association.

That group has done some good research on the subject, and the document provides an excellent overview of the present situation.

Thank you very much for the chance to testify here this morning, sir.

[The prepared statement of Congressman McNulty, plus document mentioned above, follow:]

TESTIMONY OF CONGRESSMAN JAMES F. McNULTY, Jr.
before the
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY
February 9, 1984

Madame Chairman, I am most grateful for the opportunity to testify before this panel today on the subject of the national nuclear waste disposal program. This is a matter of tremendous importance and concern to all Americans, and you are to be commended for your panel's continuing and diligent interest in it.

My testimony addresses a critical element in our overall high-level radioactive waste disposal program, and that is the material that eventually will be used in fashioning the canisters for underground burial of the waste.

The Nuclear Waste Policy Act of 1982 requires the Department of Energ to develop two national repositories for high level waste from this nation's nuclear power plants, of which there are now 88. Both sites will employ a system known as the multiple barrier containment concept, which calls upon both the containment canister and the surrounding geology to prevent radioactivity from entering the biosphere.

The decisions eventually reached by DOE and Congress on the details o this program are the decisions with which we, our children, and many futur generations must live.

With the importance of this matter in mind, we should consider the approach taken by a government that has already gone through this process: Sweden. In its study of radioactive waste disposal ending last year, Sweden sought, unsuccessfully, to find a method of waste disposal that was absolutely, permanently safe. When such a system could not be found, Sweden opted for a system which its study indicated would be safe for hundreds of thousands -- perhaps a million -- years. That system involves the use of copper canisters surrounded by clay and placed in crystalline rock. The conclusions reached in the Swedish study were confirmed in a 1980 study by the National Research Council of our own National Academy of Sciences.

By comparison, the objective of the study underway in the United States today appears to be the development of a system that can "provide a reasonable assurance that the public and the environment will be adequatel protected." The Nuclear Waste Policy Act does not require anything more substantial, and this minimum requirement appears to be the aim of the Department of Energy today.

DOE presently is researching the use of stainless steel canisters placed in salt formations. Such a canister in such an environment would have a life expectancy of between 300 and 1,000 years. After that, the canister will fail, and radiation will leak into the salt formation. From that point on, we will be relying on the stability of the geology to prevent the radioactivity from reaching the biosphere.

The fundamental difference between the Swedish approach and the American approach has concerned the cannister material and the role it plays in the long-term containment of the radioactivity. The Swedes studied copper, and found that it will last hundreds of thousands of years -- placed in the proper environment. The United States is studying stainless steel, and has virtually conceded that it would only be good for 300 to 1,000 years, even in its optimum environment.

Clearly, copper must pose some other problems, or it would have been under study as well. From what I have been able to discern, none of these problems are insurmountable.

Until recently, copper was considered a difficult metal to weld. Technological advances have changed this, however. The Swedish government has identified a process known as "hot isostatic pressing," and other studies have determined that the process of electron beam welding will allow copper to be welded properly.

Questions have also been raised concerning copper's resistence to corrosion. Energy Secretary Donald Paul Hodel has stated that copper is "less resistant to corrosion than other candidate materials." In a salt environment, research has shown that this is true. However, researched in a crystalline rock environment such as that used by the Swedes, copper has more than proven its durability.

On two occasions, the Department of Energy referred to copper as "a critical natural resource" in explaining why it was not being studied. If the word "critical" implies that the metal is in short supply or is expensive, it should be noted that a global copper surplus of more than 750,000 metric tons exists today, and that the world copper price, at 65 cents per pound, is at its lowest point in real terms in this century. And if "critical" implies that the metal is vital to our nation's security, then I must question why this Administration has not purchased a single pound of copper for the national strategic stockpile, even though that stockpile today is barely 29,000 tons, less than 3 percent of the national security level of 1 million tons as determined by the Federal Emergency Management Agency.

Finally, copper has not been studied because it is reportedly too expensive. The use of stainless steel in this program would be less expensive than copper by about 10 percent, according to estimates. But I believe that enough evidence exists that copper may be significantly safer than stainless steel, under the proper circumstances. If we can prove that to be the case, through research, then it may very well follow that some additional cost would be worthwhile. We should not take chances with our long-term radioactive waste disposal program. To do so is to put our future generations at risk. To provide anything less than the safest disposal system, for the sake of economics, would be shortsighted and dangerous.

I want to say that I am not a bit embarrassed to plead a parochial interest in the use of copper in the nuclear waste disposal program. My district in southeastern Arizona produces about half the copper produced in this country, and it is true beyond doubt that our domestic industry would find such a program to be a significant and valuable new market. For an industry that is operating today at barely half the level of five years ago, the adoption of copper as the material for nuclear waste disposal could mean a new market for as much as 2 million metric tons of copper, according to industry estimates. That is greater than the largest overall single-year production figure in the history of the domestic industry, and for an industry that is not enjoying economic recovery like the rest of the nation, that is significant.

Secretary Hodel testified on Tuesday of this week before the Subcommittee on Energy and Environment of the House Interior Committee. I am not a member of that subcommittee and was not present at the hearing, but I am a member of the Interior Committee and have worked very closely on this issue with Chairman Morris K. Udall. I am pleased to be able to report that the Secretary has indicated that DOE will now begin to study the use of copper in the canister program. This is an important step forward, and I would like to assure this panel that I will be more than willing to work toward the adoption of any legislation that might be necessary to accommodate the expanded study.

Once we have made this decision, we are locked in. The decision will affect many lives for many years, and it deserves careful consideration. Congress must ensure that such consideration is given.

Madame Chairman, with the subcommittee's approval I would like to submit for the record a background document entitled "A Perspective on Potential Uses for Copper in High-Level Radioactive Waste Disposal," prepared by Arizona's copper mining supply association, AMIGOS. The association has done some valuable research into the subject, and this document provides an excellent overview of the present situation.

Thank you again for the opportunity to testify today.

# # #

A PERSPECTIVE ON
POTENTIAL USES FOR COPPER
IN HIGH-LEVEL RADIOACTIVE WASTE DISPOSAL

AMIGOS
P.O. Box 28191
Phoenix, Arizona 85002

THE ISSUE

Current research into methods of nuclear waste disposal has been placing heavy emphasis on steels for enclosure (canister) material in the waste package. While steels are good, copper may be better for placement in certain types of geologic repository environments. Additionally, use of copper as the encapsulation material for high-level radioactive wastes may offer the advantage of decreasing the need to rely on complex performance models.

CURRENT RESEARCH ASSUMPTIONS

With the selection of steel as the canister reference material, current research at the project level appears to assume eventual failure of the canister. This failure would be presumed to occur within the 300 to 1,000 year criterion for canister integrity promulgated by the Nuclear Regulatory Commission in its Final Rule (10 CFR 60.113).

Because of this assumption of canister failure, researchers must look into such difficult issues as canister corrosion, including mechanisms for such corrosion and break-through time; package materials interaction research must consider how ground waters plus the heat generated during the waste's thermal period will accelerate or retard corrosion; and once the canister is breached, researchers must consider how release rates of radionuclides are to be calculated. Potential for radionuclide migration to the biosphere must be extensively modeled.

The assumption that the canister will eventually corrode and fail, releasing radioactive waste, requires extensive and exhaustive research into the host rock's performance as a redundant portion of the engineered barrier. Further, the assumption of canister corrosion and eventual failure means heavy reliance on extraordinarily complex performance models.

A SIMPLER PATHWAY FOR RESOLUTION OF RESEARCH ISSUES

Rather than consider the canister a sacrificial barrier, a simpler research and development pathway would be to look at the canister as the primary means of waste containment. Identify, design and demonstrate a high integrity, essentially permanent waste package. Such a package, with its canister, should exhibit long-term thermodynamic stability, low soluability, have adequate tensile strength, not become brittle, provide for durability in the radiation field and provide for a high integrity seal.

AMIGOS
P.O. Box 25191
Phoenix, Arizona 85002

With the canister as the primary waste containment mechanism, less extensive research would need to be done on geologic barriers. The rock would become the backup barrier and could be researched from the perspective of unlikely and unanticipated breaches of canister integrity, rather than from the perspective that canister failure is a "sure thing".

COPPER IN NON-SALT REPOSITORIES

In certain geologic media, copper offers the advantages of thermodynamic stability, low soluability, adequate tensile strength and ductility, and lack of brittleness.

Figure (1) charts the range in which certain substances begin to absorb oxygen...a first step toward corrosion. The heavy line is a reference line for basalt rock. Those metals below the heavy line; iron (Fe) and titanium (Ti), would oxidize faster than the basalt could absorb oxygen. Above the heavy line, the rock would soak up oxygen faster than would the metals illustrated by the lighter lines, nickel (Ni) and copper (Cu). The rock would keep the oxygen in a basalt repository, away from the copper by a wide safety margin. Hence, copper's corrosion rate in basalt would be nil. A copper canister in basalt rock could serve as a permanent containment mechanism.

AMIGOS
P.O. Box 25191
Phoenix, Arizona 85002

Copper could perform with a slightly narrower margin between host rock and metal in a crystalline rock (granite) repository.

This phenomenon has been extensively documented by Swedish Nuclear Fuel Supply Co. (KBS) and the principle has been affirmed by the U. S. National Academy of Sciences in its January 16, 1980 paper entitled "A Review of the Swedish KBS 2 Plan For Disposal of Spent Nuclear Fuel".

POTENTIAL DISADVANTAGES OF COPPER

Cost is the first disadvantage cited when copper is proposed as canister material. This objection, however, is usually predicated on a pound-for-pound comparison. In a disposal philosophy which considers the canister/waste package the primary barrier to spillage, the additional materials cost can be offset by diminished research requirements for geology, radionuclide migration and other areas of geologic concern.

There remain two open research questions with respect to copper: (1) long-term performance under radiation, and (2) sealability. Technologies for sealing copper reliably are available, but they are non-standard and would have to be proven in the laboratory. Both of these subjects could be areas for additional research funding under the Nuclear Waste Terminal Storage program.

AMIGOS
P.O. Box 25191
Phoenix, Arizona 85002

COSTS OF ADDITIONAL RESEARCH

Research to answer the two open questions cited above could be done for approximately $500,000 per year over the next four to five years. Such funds would need to be specifically allocated to a geologic environment in which copper could fulfill its potential as the primary and permanent barrier to leakage of radioactive wastes. These would be the Basalt Waste Isolation Project (BWIP) at Hanford, WA; any crystalline rock projects to be named at a later date; and possibly, any other non-salt environments which might be investigated.

PUBLIC CONSIDERATIONS

A nuclear waste disposal philosophy which says, in essence: "After the garbage can rots away, we hope nature will take the course we have predicted it will", would be a difficult one to explain to the public at large. A containment mechanism which is permanent, offering protection from radioactive wastes over an infinite amount of time seems more acceptable to concerned citizens. A copper canister in appropriate geologic environments would accomplish that purpose.

CONCLUSIONS

Copper can be expected to provide permanent containment of radioactive wastes in appropriate geologic media. Use of a copper canister in the waste package would permit a reversal of research priorities from geologic considerations to waste package issues at certain of the current research projects. Permanent containment of nuclear wastes certainly would be more acceptable from the standpoint of environmental considerations and the public safety.

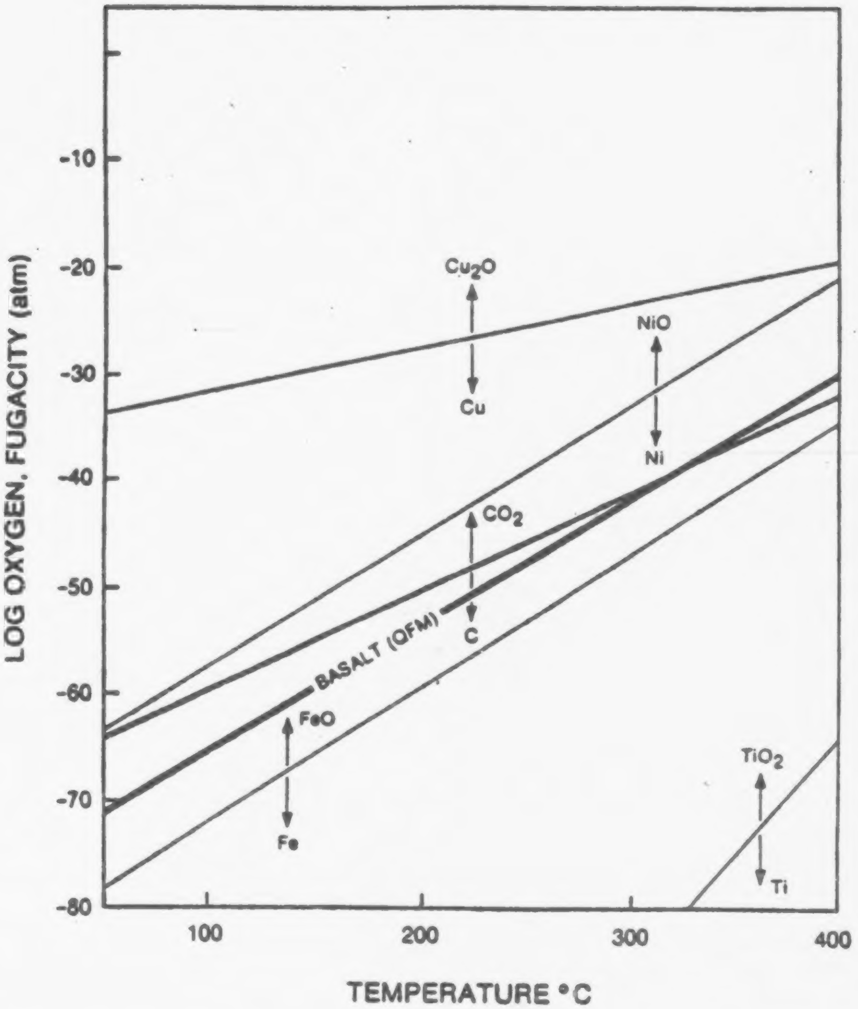
PROPOSAL

Research funding for specific copper-related issues should be increased.

Evaluation of copper should be the subject of increased visibility within the Department of Energy, within the research community and with the public.

AMIGOS
P.O. Box 25191
Phoenix, Arizona 85002

(Figure 1.)



STABLE REGIONS OF SOME METALS AND OXIDES PERTINENT TO NUCLEAR WASTE DISPOSAL IN BASALT

Mr. VALENTINE. Thank you very much, Jim. It is good to see you. I don't have any questions to ask you. We will receive the documents that you referred to either now or at some reasonable time in the future. Thank you very much.

Mr. McNULTY. I am most grateful.

Mr. VALENTINE. The next witness is Mr. Donald B. Mausshardt. If you will come around, sir, we are ready to hear from you at this time.

Mr. Mausshardt is Deputy Director, Office of Nuclear Materials Safety and Safeguards at the Nuclear Regulatory Commission.

We, of course, will receive and put in the record *in toto* your statement, and you may just proceed any way you deem appropriate. You can summarize from that or read the whole thing. We have got plenty of time.

Mr. MAUSSHARDT. Thank you, Mr. Chairman. I will summarize my statement in the interest of saving your time.

Mr. VALENTINE. Thank you.

STATEMENT OF DONALD B. MAUSSHARDT, DEPUTY DIRECTOR, OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS, NUCLEAR REGULATORY COMMISSION; ACCOMPANIED BY RICHARD CUNNINGHAM AND ROBERT BROWNING

Mr. MAUSSHARDT. I am Donald Mausshardt, Deputy Director from the Office of Nuclear Material Safety and Safeguards. Accompanying me, on my right, is Mr. Robert Browning, Director of the Waste Management Division, responsible for the National Waste Policy Act functions at NRC, and on my left is Mr. Richard Cunningham. He is the Director of the Division of Fuel Cycle and Material Safety and is responsible for West Valley and for the remedial action program.

It is a privilege to be here to appear before you today to review NRC's relationship with the Department of Energy and the implementation of the Nuclear Waste Policy Act of 1982. We will address what we understand to be the subcommittee's interests in the NRC relationship with DOE, activities concerning both remedial actions and the West Valley demonstration project.

I will briefly summarize the activities to date under the Waste Policy Act and try to describe our working relationship with DOE.

As you know, most of the actions required under the National Waste Policy Act are to be carried out by DOE. The NRC's statutory role is to provide an independent determination that the DOE is carrying out certain of its responsibilities in a manner that will protect public health and safety and the environment. The direct consequence of that relationship, for the most part, is that NRC must develop its plans to be responsive to DOE's lead and tailor its program to DOE's plans and schedules.

NRC has two principal roles to perform in order to accomplish the actions as mandated under the act. The first deals with rulemaking.

The act assigns responsibility to the Nuclear Regulatory Commission for certain independent actions. There are four rules during the past year that NRC has worked on.

The first deals with promulgating technical requirements and criteria for licensing of the geologic repository. The second deals with special procedures for hearings on licenses, applications for facility expansions of spent fuel storage capacity and transshipment of spent fuel. The third, NRC is to develop procedures and criteria for determining an applicant's eligibility for Federal interim spent fuel storage. The fourth deals with NRC's responsibilities to promulgate regulations or other suitable guidance for the training and qualification of civilian nuclear powerplant personnel.

The second and probably most significant activity that NRC has been involved in with DOE is its efforts, under the National Waste Policy Act, to review ongoing DOE activities which will provide data, assessments, and designs necessary to permit DOE to file a high-quality construction authorization application.

This interaction between DOE and NRC is provided so that the issues can be identified early and the resolution taken at a time when it would hopefully be least costly and least disruptive. These interactions will continue to have a close NRC management attention to insure that we maintain an effective exchange of information.

In addition, NRC is also working closely with DOE to develop its planning and scheduling activities to accomplish those portions of the act which DOE has primary responsibility. There are three activities on which we have been working with DOE which I will just briefly mention here.

First, section 112(A) requires that NRC concur in DOE's repository siting guidelines which we have currently under review at the agency. We are working on a schedule right now that will enable the Commission to reach a decision by the end of April.

The second, NRC is to coordinate with DOE in the development of DOE's mission plan.

The third is that NRC is to reach a written understanding with DOE on the procedures for interagency involvement during the development and operation of a test and evaluation facility. Should DOE decide to pursue this option, the NRC will be ready to move forward with a written understanding concerning this facility.

Turning to the West Valley demonstration project, we understand that the subcommittee is also interested in the DOE/NRC interaction on West Valley. We should point out that although the West Valley Act is slightly different than the Nuclear Waste Policy Act, it does have an important interaction. Under the West Valley Demonstration Project Act NRC does not exercise licensing authority but has a safety oversight role in which we are to review, comment, and consult on DOE plans and activities and, of course, have access to the site to monitor ongoing work. An agreement between DOE and NRC has been developed which describes the relationship between the two agencies.

In addition, we have also been participating with DOE on the review and comment of the overall solidification project as specified by the act, but that document has not yet been submitted *in toto* to the agency.

Also, we have been participating with the Department of Energy on the quality assurance program for waste solidification. DOE has incorporated our comments to improve both the auditing procedures and the solidification program itself. The improved QA program which is in effect for the construction of the test stand which may be used later for actual waste processing.

We have been closely following DOE's use of the facility radioactive waste disposal area as well. The two agencies have been cooperating on an ongoing program to understand better the confinement capability of the disposal area. DOE is now studying whether mitigative remedial work may be necessary in the disposal area to maintain a safe containment and particularly for long-term periods of time.

In summary, the DOE/NRC interface and relationship, from the NRC perspective at West Valley, has been very satisfactory.

Regarding the nuclear waste fund, I understand the subcommittee is interested in NRC plans and activities with DOE concerning some funding of the NRC from the nuclear waste fund as established under the act. The NRC is examining this issue but has not yet come to a conclusion as to how we can do this.

The contaminated sites program, concerning DOE's contamination research and development activities at various sites and vicinity properties, is covered under the 1984 DOE Appropriation Act. I would like to clarify that, under the current law, NRC has a very limited role. NRC has worked with DOE on remedial action on formerly licensed sites and has provided information from our licensing files at DOE's request. I again would remind the committee that NRC not does have any formal licensing or concurrence role, though, in any of these activities.

The only formal role that NRC has in DOE remedial action program is in connection with the uranium mill tailings program, title I sites. In that program, NRC's concurrence is required for certain DOE remedial action activities such as the acquisition of properties or the removal of radioactive residual material. The maintenance of stabilized sites will be under NRC license.

In addition, NRC has examined its own records to identify old sites which may require remedial actions. Under current NRC rules, an NRC lecensee's responsibilities cannot be terminated until he can show that the site has been decontaminated to levels of acceptable use.

In summary, we believe our relationship over the last year has been quite productive. Currently, we believe that there is a significant need for the waste program to focus and achieve stability. We believe that this can be achieved through the prompt completion of the mission plan and a project decision schedule. If this is done, it would go far in providing both the focus and stability for this program.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Mausshardt follows:]

TESTIMONY OF THE U.S. NUCLEAR REGULATORY COMMISSION

MADAM CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE,

IT IS A PRIVILEGE TO APPEAR TODAY TO REVIEW NRC'S RELATIONSHIP WITH THE DEPARTMENT OF ENERGY (DOE) IN THE IMPLEMENTATION OF THE NUCLEAR WASTE POLICY ACT OF 1982 (NWPA). WE WILL ALSO ADDRESS WHAT WE UNDERSTAND TO BE THE SUBCOMMITTEE'S INTERESTS IN NRC'S RELATIONSHIP WITH DOE'S ACTIVITIES CONCERNING REMEDIAL ACTIONS AND THE WEST VALLEY DEMONSTRATION PROJECT ACT.

NWPA - NRC ACTIVITIES

I WILL BRIEFLY SUMMARIZE NRC ACTIVITIES TO DATE UNDER THE WASTE POLICY ACT.

AS YOU KNOW, MOST OF THE ACTIONS REQUIRED UNDER NWPA ARE TO BE CARRIED OUT BY DOE, AND THE COMMISSION'S STATUTORY ROLE IS TO PROVIDE AN INDEPENDENT DETERMINATION THAT DOE IS CARRYING OUT CERTAIN OF ITS RESPONSIBILITIES IN A MANNER THAT WILL PROTECT THE PUBLIC HEALTH AND SAFETY AND THE ENVIRONMENT. THE DIRECT CONSEQUENCE OF THIS RELATIONSHIP IS THAT, FOR THE

MOST PART, NRC MUST DEVELOP ITS PLANS TO BE RESPONSIVE TO DOE'S LEAD AND TAILOR ITS PROGRAM TO DOE'S PLANS AND SCHEDULES.

NRC HAS TWO PRINCIPAL ROLES TO PERFORM IN ORDER TO ACCOMPLISH THE ACTIONS MANDATED UNDER NWPA.

NRC RULEMAKING

FIRST, THE ACT ASSIGNS PRIMARY RESPONSIBILITY TO NRC FOR CERTAIN INDEPENDENT RULEMAKING ACTIONS. ACCORDINGLY, DURING THE PAST YEAR, NRC WORKED ON THE FOLLOWING:

° UNDER SECTION 121(B), NRC IS REQUIRED TO PROMULGATE TECHNICAL REQUIREMENTS AND CRITERIA FOR LICENSING A GEOLOGIC REPOSITORY FOR DISPOSAL OF HIGH-LEVEL RADIOACTIVE WASTE OR SPENT FUEL BY JANUARY 1984. THE COMMISSION PROMULGATED ITS FINAL 10 CFR PART 60 TECHNICAL CRITERIA ON JUNE 21, 1983.

- Under Section 134, NRC is to develop special procedures for hearings on licensees applications for facility expansions of spent fuel storage capacity and transshipment of spent fuel. On December 5, 1983, the Commission published for comment proposed amendments to our 10 CFR Part 2 licensing procedures. The comment period ends February 20, and we expect to submit a final rule for the Commission's review by early April.
- Under Sections 135(b) and 135(g), NRC is to develop procedures and criteria for determining an applicant's eligibility for federal interim spent fuel storage. The Commission published a proposed rule on April 29, 1983, and received numerous comments from the public. We expect to submit a final rule for the Commission's review by the end of February.
- Under Section 306, NRC must promulgate regulations or other suitable Commission guidance for the training and qualifications of civilian nuclear power plant

PERSONNEL. THE COMMISSION SENT A LETTER TO CONGRESS ON JANUARY 20 OUTLINING PROPOSED REVISIONS TO EXISTING NRC RULES AND ASSOCIATED GUIDANCE ON REACTOR AND OPERATOR LICENSING. THE CURRENT SCHEDULE CALLS FOR PUBLICATION OF A PROPOSED RULE IN EARLY MARCH, WITH REVISIONS FOR PUBLIC COMMENTS AND FINAL PROMULGATION BY NOVEMBER.

NRC REVIEW OF DOE TECHNICAL ACTIVITIES

SECONDLY, NRC'S MAJOR EFFORT UNDER NWPA IS TO REVIEW ONGOING DOE TECHNICAL ACTIVITIES WHICH WILL PROVIDE THE DATA, ASSESSMENTS, AND DESIGNS NECESSARY TO PERMIT DOE TO FILE A HIGH QUALITY CONSTRUCTION AUTHORIZATION APPLICATION. THIS INTERACTION BETWEEN DOE AND NRC IS PROVIDED SO THAT ISSUES CAN BE IDENTIFIED EARLY AND RESOLUTION UNDERTAKEN AT A TIME WHEN IT WILL BE LEAST COSTLY AND LEAST DISRUPTIVE. THESE INTERACTIONS WILL CONTINUE TO HAVE CLOSE NRC MANAGEMENT ATTENTION TO ENSURE WE MAINTAIN AN EFFECTIVE EXCHANGE OF INFORMATION.

DOE/NRC COORDINATION

IN ADDITION NRC IS WORKING CLOSELY WITH DOE ON THE DEVELOPMENT OF ITS PLANNING AND SCHEDULING ACTIVITIES TO ACCOMPLISH THOSE PORTIONS OF THE NWPA FOR WHICH DOE HAS THE PRIMARY RESPONSIBILITY. OVER THE PAST YEAR, NRC HAS BEEN WORKING ON SEVERAL ACTIVITIES OF THIS TYPE:

- SECTION 112(A) REQUIRES NRC CONCURRENCE IN DOE'S REPOSITORY SITING GUIDELINES FOR COMMISSION CONCURRENCE. STATE AND TRIBAL PETITIONS FOR FORMAL RULEMAKING ON THIS CONCURRENCE DECISION LED THE COMMISSION TO PROVIDE A PUBLIC MEETING FOR INTERESTED PARTIES TO COMMENT ON THE GUIDELINES SUBMITTED BY DOE, AND AN OPPORTUNITY TO COMMENT ON THE PROPOSED COMMISSION DECISION. AT THE PUBLIC MEETING, HELD ON JANUARY 11, THE COMMISSION RECEIVED ORAL AND WRITTEN COMMENTS FROM EIGHT STATES, ONE TRIBE, REPRESENTATIVES OF INDUSTRY AND CITIZENS GROUPS, EPA, AND DOE. AT THE STATES'

REQUEST, THE RECORD WAS HELD OPEN FOR ADDITIONAL COMMENTS UNTIL FEBRUARY 1. WE ARE CURRENTLY WORKING TO A SCHEDULE THAT WILL ENABLE THE COMMISSION TO REACH A DECISION BY THE END OF APRIL.

- UNDER SECTION 301(B), NRC IS TO COORDINATE WITH DOE IN THE DEVELOPMENT OF DOE'S MISSION PLAN. WE ARE PLEASED THAT DOE HAS GIVEN US AN ADDITIONAL OPPORTUNITY FOR COMMENT BY SUBMITTING AN EARLY DRAFT OF ITS OVERVIEW AND CURRENT PROGRAM PLANS -- THE FIRST OF TWO VOLUMES -- FOR OUR REVIEW ON DECEMBER 23, 1983. WE EXPECT TO RECEIVE AN UPDATED VERSION OF THIS DOCUMENT, TOGETHER WITH THE SECOND VOLUME SETTING FORTH PROGRAM MILESTONES AND RESOURCE ESTIMATES IN MORE DETAIL, BY THE STATUTORY DEADLINE OF APRIL 7. WE INTEND TO PUT HIGH PRIORITY ON CONDUCTING A THOROUGH REVIEW TO ENABLE THE COMMISSION TO

COMMENT IN TIME FOR DOE TO MEET ITS NWPA DEADLINE OF JUNE 7 TO SUBMIT THE MISSION PLAN TO CONGRESS.

WE ARE AWARE THAT DOE WILL BE EVALUATING ITS CURRENT OVERALL PROGRAM PLANS AS IT DEVELOPS THE DETAILED ESTIMATES OF TIME AND RESOURCE NEEDS IN THE SECOND VOLUME OF THE MISSION PLAN, AND WE INTEND TO WORK CLOSELY WITH DOE AS IT REVISES THE PLAN. WE ANTICIPATE THAT THE FINAL MISSION PLAN SUBMITTED TO CONGRESS WILL REFLECT THE COMMISSION'S LICENSING PROCESS, THE TIME REQUIRED TO GAIN PUBLIC ACCEPTANCE OF CRITICAL DECISIONS WHICH EXPERIENCE TO DATE HAS SHOWN TO REQUIRE MORE TIME THAN ANY OF US HAVE ESTIMATED, AND A MANAGEMENT RESERVE COMMENSURATE WITH THE UNCERTAINTIES AT THIS STAGE OF THE PROGRAM.

- UNDER SECTION 217(F)(1), NRC IS TO REACH A WRITTEN UNDERSTANDING WITH DOE ON PROCEDURES FOR INTERAGENCY INTERACTION DURING DEVELOPMENT AND OPERATION OF A TEST AND EVALUATION FACILITY (TEF), SHOULD DOE DECIDE TO PURSUE THIS OPTION. WHEN DOE MAKES ITS DECISION, NRC WILL BE READY TO MOVE TOWARD THE WRITTEN UNDERSTANDING CONCERNING THIS FACILITY.

WEST VALLEY DEMONSTRATION PROJECT - NRC OVERSIGHT

WE UNDERSTAND THAT THE SUBCOMMITTEE IS ALSO INTERESTED IN NRC-DOE INTERACTION ON THE WEST VALLEY DEMONSTRATION PROJECT, WHICH DOES NOT ARISE FROM THE WASTE POLICY ACT, BUT COULD HAVE IMPORTANT EFFECTS ON THE NATIONAL HIGH-LEVEL WASTE PROGRAM. UNDER THE WEST VALLEY DEMONSTRATION PROJECT ACT, NRC DOES NOT EXERCISE LICENSING AUTHORITY BUT HAS A SAFETY OVERSIGHT ROLE IN WHICH WE ARE TO REVIEW, COMMENT, AND CONSULT ON DOE PLANS AND ACTIVITIES, AND HAVE ACCESS TO THE SITE TO MONITOR ONGOING WORK. AN AGREEMENT BETWEEN DOE AND NRC DESCRIBED THE RELATIONSHIPS BETWEEN THE

AGENCIES FOR THIS PROJECT. NRC STAFF HAVE BEEN IN CLOSE COMMUNICATION WITH DOE SINCE ITS ARRIVAL AT THE SITE ON FEBRUARY 25, 1982, AND WE HAVE MADE A NUMBER OF SITE VISITS. THE DOE/NRC INTERFACE HAS BEEN VERY SATISFACTORY WITH BOTH AGENCIES STAFFS FREELY EXCHANGING DATA.

WE HAVE NOT YET RECEIVED FROM DOE FOR OUR REVIEW AND COMMENT THE OVERALL PLAN FOR THE SOLIDIFICATION PROJECT AS SPECIFIED BY THE ACT, BUT THIS IS SCHEDULED FOR LATER THIS FISCAL YEAR. DOE HAS CONSULTED WITH US ON TWO KEY ELEMENTS OF THE PLAN -- SELECTION OF THE WASTE FORM AND SELECTION OF THE SOLIDIFICATION PROCESS.

WE PARTICIPATED IN AN AUDIT OF DOE'S QUALITY ASSURANCE PROGRAM FOR WASTE SOLIDIFICATION, AND DOE HAS INCORPORATED OUR COMMENTS TO IMPROVE BOTH THE AUDITING PROCEDURES AND THE SOLIDIFICATION PROGRAM ITSELF. THE IMPROVED QA PROGRAM WAS IN EFFECT FOR CONSTRUCTION OF THE COMPONENT TEST STAND, WHICH MAY BE USED LATER FOR OPERATION WITH THE ACTUAL WASTES.

WE HAVE BEEN CLOSELY FOLLOWING DOE'S USE OF THE FACILITY RADIOACTIVE WASTE DISPOSAL AREA AS WELL. THE TWO AGENCIES HAVE BEEN COOPERATING ON AN ONGOING PROGRAM TO UNDERSTAND BETTER THE CONFINEMENT CAPABILITY OF THE DISPOSAL AREA. DOE IS NOW STUDYING WHETHER MITIGATIVE REMEDIAL WORK MAY BE NECESSARY IN THE DISPOSAL AREA TO MAINTAIN SAFE CONTAINMENT, PARTICULARLY FOR LONG TERM PERIODS.

NUCLEAR WASTE FUND

I UNDERSTAND THE SUBCOMMITTEE IS INTERESTED IN NRC PLANS AND ACTIVITIES WITH DOE CONCERNING SOME FUNDING OF NRC FROM THE NUCLEAR WASTE FUND ESTABLISHED UNDER NWPA. THE NRC IS EXAMINING THIS BUT AS OF NOW HAS NOT COME TO A CONCLUSION ON HOW THIS COULD BE DONE.

CONTAMINATED SITES PROGRAM

CONCERNING DOE'S DECONTAMINATION RESEARCH AND DEVELOPMENT ACTIVITIES AT THE VARIOUS SITES AND VICINITY PROPERTIES COVERED

UNDER THE 1984 DOE APPROPRIATION ACT, I WOULD LIKE TO CLARIFY THAT UNDER CURRENT LAW, NRC HAS A VERY LIMITED ROLE. NRC HAS WORKED WITH DOE ON REMEDIAL ACTION ON FORMERLY LICENSED SITES, AND WE HAVE PROVIDED INFORMATION FROM OUR LICENSING FILES AT DOE'S REQUEST. NRC HAS NO FORMAL LICENSING OR CONCURRENCE ROLE IN ANY OF THESE ACTIVITIES, HOWEVER. THE ONLY FORMAL NRC ROLE IN DOE REMEDIAL ACTIONS IS IN CONNECTION WITH THE URANIUM MILL TAILINGS REMEDIAL ACTION PROGRAM (TITLE I) SITES. IN THAT PROGRAM, NRC CONCURRENCE IS REQUIRED FOR CERTAIN DOE REMEDIAL ACTIVITIES, SUCH AS ACQUISITION OF PROPERTIES OR REMOVAL OF RESIDUAL RADIOACTIVE MATERIALS, AND MAINTENANCE OF STABILIZED SITES WILL BE UNDER NRC LICENSE. IN ADDITION, NRC HAS EXAMINED ITS RECORDS TO IDENTIFY OLD SITES WHICH MAY REQUIRE REMEDIAL ACTION. UNDER CURRENT NRC RULES THE LICENSEE'S RESPONSIBILITIES CANNOT BE TERMINATED UNTIL HE CAN SHOW THAT THE SITE HAS BEEN DECONTAMINATED TO LEVELS ACCEPTABLE FOR UNRESTRICTED USE.

SUMMARY

IN CLOSING, WE BELIEVE OUR RELATIONSHIP WITH DOE OVER THE LAST YEAR HAS BEEN PRODUCTIVE. CURRENTLY, WE BELIEVE A SIGNIFICANT NEED IN THE WASTE PROGRAM IS FOR FOCUS AND STABILITY. WE BELIEVE A SUCCESSFUL AND PROMPT COMPLETION OF THE MISSION PLAN -- AND PROJECT DECISION SCHEDULE -- WOULD GO FAR IN PROVIDING THIS FOCUS AND STABILITY.

THANK YOU FOR THIS OPPORTUNITY TO PROVIDE OUR VIEWS. I WILL BE HAPPY TO RESPOND TO ANY QUESTIONS.

Mr. VALENTINE. Thank you, Mr. Mausshardt.

I want to direct your attention to some concerns that have been expressed to Mrs. Lloyd, the chairman of the subcommittee, and direct your attention to the statute which was signed by the President and became the law of the land a little over a year ago. It states in section 112 that:

> Not later than 180 days from the date of the enactment of this Act, the Secretary, following consultation with the Council on Environmental Quality, the Administrator of the Environmental Protection Agency, the Director of the Geological Survey, and interested Governors in the concurrence of the Commission, shall issue general guidelines for the recommendation of sites for repositories.

Now, some concern has been expressed to the chairman and other members of this committee as to why the Nuclear Regulatory Commission is taking such a long time to provide its assent to the guidelines which were submitted by the DOE. Could you address that?

Mr. MAUSSHARDT. Yes, sir. In fact, Mr. Browning here will also probably be commenting on this with me.

The Nuclear Regulatory Commission received the DOE guidelines in late November, if I am not mistaken, and at that time, instigated immediate review of the documents. There was some concern in our interaction with DOE as to the volume of comments that were raised when we got the document. The Commission decided in January, early January, to hold a public meeting to gather information on the guidelines themselves. At that time, the Commission then directed the staff to report back to them, based on comments and testimony received by the end of April, so that they could make a decision on the guidelines, and that is the schedule we have been working under, sir.

Mr. VALENTINE. You know, we all realize that this is a real problem, and you run into a lot of different interests, and you run into a lot of people with different ideas, and so on. But, do you, not just as a public official, but do you believe, as a citizen of the United States of America and a fellow traveler on the face of the Earth, that we are doing everything that we can or should do as a nation to approach this problem and to try to be sure that we make the right decisions with respect to how to handle the waste material that comes from such fantastic progress so that we won't leave a big trash heap for people in the next two or three centuries?

Mr. MAUSSHARDT. I can agree with you that we have got to be very careful on our decisions because of the criteria, citing guidelines will basically drive the program, sir. I think the Commission's concern in this area was that they wanted to be sure that the public was heard, the record was complete before they went forward.

Mr. VALENTINE. What do you think that the NRC's role should be to determine consistency with the regulations? Or is that what you consider the role to be, to determine the consistency with the regulations?

Mr. BROWNING. That is the main emphasis of the staff's review of the guidelines that are in the House today is that they are consistent with our regulation and will we end up with sites that are reasonable candidates for repository, using the process and the conditions that are laid out in the guidelines?

Mr. VALENTINE. Have you had any States or any areas in the United States to volunteer to serve as repositories?

Mr. MAUSSHARDT. No, not to my knowledge.

Mr. VALENTINE. You haven't selected any, I take it.

Mr. BROWNING. No, we have not. We do not select repositories.

Mr. VALENTINE. You certainly haven't selected any in the Second District of North Carolina.

Mr. MAUSSHARDT. No, sir. DOE will be the lead agency on that, sir.

Mr. VALENTINE. Thank you very much, gentlemen.

I don't want to claim that this is the highlight of the morning, but the next gentleman is Mr. Sherwood Smith. He is chief executive officer of the great Carolina Power & Light Co. in Raleigh, N.C. He represents the Edison Electric Institute, and he is a good man and a good friend of mine and a neighbor, and I want to welcome him here today. Mr. Smith, we will put in the record your prepared statement and you can summarize it or proceed in any way you deem appropriate. It is good to see you here.

STATEMENT OF SHERWOOD H. SMITH, JR., CHIEF EXECUTIVE OFFICER, CAROLINA POWER & LIGHT REPRESENTING EDISON ELECTRIC INSTITUTE

Mr. SMITH. Thank you very much, Mr. Valentine. It is a pleasure to be here before the committee, particularly with you presiding today.

With me today is Dr. E. Linn Draper, senior vice president of Gulf States Utility Co.

We do have a prepared witness statement that has been submitted for the record, and if I may summarize briefly, I will proceed.

We are here today on behalf of the electric utility and nuclear industries to express some concern about the developments since the enactment of the Nuclear Waste Policy Act of 1982. The concern arises because our customers, through our organizations, are now paying more than $25 million a month into the nuclear waste fund, and, as additional nuclear units come into service, these payments will rise to about $50 million a month. They will eventually total between $15 and $25 billion .

If, in this country, we are to manage our nuclear waste in a rational and economic manner for the benefit of the customers who use nuclear-generated electricity, we must be able to rely on a date certain to begin transferring spent fuel to the Federal Government, and that date should be the date in 1998 as provided under the act.

In adopting the nuclear waste policy legislation, Congress recognized three essential facts. First, nuclear power is a vital part of the Nation's electric supply. In 1983, nuclear units accounted for about 13 percent of the Nation's electricity supply. In some regions, the reliance on nuclear energy is much higher, for example, our own company. Our three nuclear units are producing more than 25 percent of our electricity this year, and will soon be producing at a much greater percentage.

As new units now come into service, up to 20 percent of American's electricity will come from nuclear power. Nuclear power is second only to coal as a primary fuel in the production of electricity in our country.

Furthermore, existing nuclear units provide some of the most economical energy we have. If the electricity generated by nuclear power in the 9-year period between 1974 and 1982 had been provided by coal, the electric consumers in this country would have paid an additional $13 billion. If that had been generated by oil instead of coal, customers would have spent an additonal $75 billion.

Congress has recognized that to continue these benefits for nuclear power, a permanent waste disposal program must be established.

Finally, it was recognized by Congress that to ever get into such a program, both a definite process and a firm timetable were absolutely indispensable.

We think the principle of the act is very sound. We want to urge that equal soundness be applied in its implementation.

Utilities, we believe, have accepted their initial responsibility under the act by signing contracts with the Department of Energy to provide funds at the rate of over $25 million a month. We are concerned that all of the other parties who are involved in this process will uphold their responsibilities and will move along expeditiously under the requirements of the act.

As Congressmen here are well aware, there are many compromises and adjustments made during the debates over this legislation. I personally was involved in the development of the legislation from the standpoint of offering testimony and observations over a period of 5 years. We accepted the legislation that was enacted. We think that no change should now be made or considered in the act in the near term, certainly. We should take the legislation that we have and begin to implement it.

The act does prescribe both a process and a schedule for carrying out the task of waste management and disposal. There is some concern that pressures have been placed on the Department of Energy to overemphasize the process at the expense of developing a firm schedule. We know that there must be some accommodation of all legitimate concerns, particularly the concerns of potential host States, and that is well provided for in the act, but we don't think that this should be done at the expense of adhering to a firm time schedule.

There are also pressures that are being placed upon the Department of Energy with respect to the uses of the funds that are now being generated. It is possible to study any particular aspect of this to death, and then restudy it, and then restudy it again. We will urge the Department of Energy to adopt as much as possible a firm fixed price contract and to adhere to expenditure of funds only for work that is absolutely essential to the development of this program, and we feel that we must do this as the representatives of our consumers who are paying this huge bill.

We think that in the implementation of the program that some stability of leadership is essential. Congress specifically carved out an area of work and designated it as the Civilian Nuclear Waste Office. The Director is to report directly to the Secretary. We think that a project management approach needs to be followed and we would hope that a permanent Director will soon be identified and placed in office there so that the program may move along.

The fiscal year 1985 budget request indicated that DOE is considering the possibility of increasing the 1 mill per kilowatt hour fee because of an estimated revenue shortfall. I think Congress, as well as the utilities and their customers, need substantial supporting justification, certainly more than is outlined in the budget document, before any increase should be considered. There is a provision in the law for the Department of Energy to borrow funds in the early years from the Treasury, so that it should not be necessary, in our opinion, to increase that fee, and we would hope that Congress would look very carefully at any proposed increases that might later come from the Department of Energy.

On the other hand, we do wish to commend the Department of Energy for the substantial progress that they have made during the first year of this project. There are nine specific accomplishments that we have described in some detail in our prepared written testimony. However, as I said earlier, a permanent director has not been nominated, a definitive and detailed repository schedule has not been provided to assure the availability of the repository in the year 1998, and a strong central control in the project office so that there will be central direction for all of the activities conducted in the field has not, as yet, been established.

We see the national laboratories, academicians, consultants, contractors all appear to be lining up with many, many requests to expend these funds on time and material, open-ended arrangements. This gives us, on behalf of our customers, your constituents, considerable concern.

Some of the States are requesting more specificity in the site selection guidelines which, in part, is natural. Yet, on the other hand, certainly no State should be allowed to manipulate the guidelines so that it has some preferred position in the selection process. We feel that the guidelines are reasonable. We have some concern that they have not already been adopted and put into place. We hope, as was stated earlier, that the NRC will be able to move expeditiously and furnish their comments. We understand that the Chairman of the NRC has said that they would be made available in April and we would hope that they would certainly be forthcoming then if not sooner.

On a different aspect of the program, I might report to you, Mr. Valentine, and others that our company, Carolina Power & Light Co. along with two other utilities, has been selected by the Department of Energy, after application, for participation in dry storage technology. This would be the development of technology that could be utilized by some utilities to expand their existing storage capacity until the repository is available in 1998. If some of these efforts are successful, then it would tend to minimize the need for the use of the federally provided minimum AFR storage.

Our own company has submitted a proposal to the Department of Energy that has been approved by them. We are currently negotiating a contract for storage of fuel at our H. B. Robinson No. 2 unit near Hartsville, S.C. which was the first unit constructed and placed into operation in the Southeastern part of the United States. That unit, I might add, has operated very successfully. It cost about $100 million initially, and it has saved our customers well over $400 million in fuel savings. All of those savings have gone directly through to the customers.

I cover the description of our spent fuel storage project in more detail in my written testimony, but essentially, it calls for the use of three modular reinforced concrete horizontal buildings which would be used to store a canister containing seven spent fuel assemblies. We would expect the project to move ahead so that we begin early next year and probably load the fuel into it in 1986.

Another aspect of this total program of waste disposal involves low-level waste disposal in this country. For a number of years, the Department of Energy has had an ongoing program, and it is important that low-level waste disposal capacity in the country be expanded to accommodate the needs both from the nuclear utility industry, hospitals, medical facilities, and so forth. Since the passage of the Low-Level Waste Policy Act of 1980, there have been a number of regional compacts entered into that have now been submitted to Congress. We have offered testimony in support of the approval of these with very specific suggestions with regard to a few of them. We hope that congressional approval will be forthcoming soon there. We stand ready to furnish additional information, certainly to cooperate with the Congress in any reasonable way that we may, in order to expedite the entire process.

[The prepared statement of Mr. Smith follows:]

EDISON ELECTRIC INSTITUTE
AMERICAN NUCLEAR ENERGY COUNCIL
UTILITY NUCLEAR WASTE MANAGEMENT GROUP
TESTIMONY BEFORE THE
COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
ON THE
FISCAL YEAR 1985 DEPARTMENT OF ENERGY BUDGET
REQUEST FOR THE COMMERCIAL NUCLEAR WASTE PROGRAM
FEBRUARY 9, 1984

Chairman Lloyd and Subcommittee members, my name is Sherwood H. Smith, Jr. I am Chairman and Chief Executive Officer of Carolina Power & Light Company. With me today is Dr. E. Linn Draper, Jr., Senior Vice President for External Affairs at Gulf States Utilities Company.

Our testimony is provided on behalf of the Edison Electric Institute (EEI), the American Nuclear Energy Council (ANEC), and the Utility Nuclear Waste Management Group (UNWMG). EEI is the association of investor-owned electric utility companies and its members generate about 76 percent of the electricity in the United States. ANEC represents over 100 organizations having an interest in nuclear power, including investor, public and cooperatively-owned utilities, manufacturers, architect-engineers, and various firms in the nuclear fuel cycle. UNWMG is a specific activity that is funded by forty-two utilities with nuclear programs, including EEI member companies, public utilities, and cooperatively-owned utilities with the sole objective of assisting in the resolution of spent fuel storage and nuclear waste disposal issues.

Recent Facts on Nuclear Energy and Electricity Demand

I would like to begin by presenting some specific facts that provide a fair view on the past performance and future productive potential of commercial nuclear energy in the United States as a necessary and essential part of this nation's energy picture.

Despite the recent publicity concerning problems being encountered at several nuclear power plants, nuclear energy in the United States is a productive technology. Last year, some 13 percent of the nation's electricity was generated by nuclear power plants. Some areas of the country have a much larger percentage of nuclear energy, and Carolina Power and Light Company now relies on nuclear energy for about 25 percent of our production. In ten years we estimate the national figure to reach about 20 percent. Nuclear energy is second only to coal in serving the nation's essential electricity generation.

The United States has 76 nuclear reactors in commercial operation--more than any other nation in the world. Six others are in the start-up phase of operation. An additional 41 units have construction permits with scheduled completion dates.

In 1984, as many as 15 of these 41 units could be ready for operating licenses. Several of these could slip over into 1985 before their licenses are obtained. The other 26 units have scheduled completion dates extending from 1985 through 1990.

Nuclear power has saved billions of dollars for the electric customers of this nation. If the electricity supplied by nuclear plants between 1974 and 1982 had been provided instead by coal or oil plants, consumers would have paid between $13 billion and $75 billion more, depending on the type of fuel substituted.

Twelve months ago, based on what we knew then of the recession and the likelihood of the economic recovery, the electric utility industry predicted that during 1983, electric output or sales might increase 1½ to 2 percent and peak demand might be 2 to 3 percent higher than 1982. However, the economic recovery was much stronger than most experts anticipated and the weather set records for both heat and cold. What actually happened was the electric output for 1983 was 3½ percent greater than for the preceding year and the peak load for the nation overall went up 7½ percent--more than double our highest earlier forecast.

Chairman Lloyd, nuclear energy plants are necessary. We will need more electricity in the future to help drive our recovering economy and maintain our standard of living. Conservation, load management and renewable energy sources are essential and helpful, but, they are simply not enough. Also, we cannot rely just on coal to provide additional capacity and to replace aging facilities.

Utility Involvement In the Nuclear Waste Program

At this point, I would like to discuss the electric utility involvement in the nuclear waste program. Utilities, under the auspices of the Utility Nuclear Waste Management Group (UNWMG), administered by EEI, and predecessor utility groups have had a coordinated program over the past nine years on a continuing basis to help bring about the necessary legislation, the regulations, and a responsible Federal nuclear waste program. As stated above, forty-two utilities with nuclear programs, both EEI member companies, and non-EEI utilities, have supported the effort. This group already has changed its emphasis to that of providing utility industry oversight of DOE and all involved Federal agencies, on the implementation of the nuclear waste legislation.

Utilities are presently making payments to the Nuclear Waste Fund of about $25 million each month, and this will increase to about $50 million each month as the plants under construction are brought on line. The overall program will last as long as there is a need to dispose of nuclear wastes. Revenues from utility payments will add up to $15 to $25 billion dollars, making this program one of the, if not actually the largest civil works project ever undertaken by this country, that will extend over many decades and funded with a user fee on electricity.

Since utilities are providing essentially all of the monies for the program, amounting to several hundred million dollars each year, it behooves us to perform, on behalf of our electricity customers, some form of a watch dog function over DOE to assure that the monies are being spent effectively and efficiently. We believe that our interest is directly in line with that of Congress, to achieve the disposal of nuclear waste in a safe manner, on a timely basis, and with an efficient and effective program that allows for state and public involvement in the decision making process.

For this reason, EEI recently established a task force made up of Chief Executive Officers, of which I am a member, to evaluate the industry overview efforts provided by UNWMG, EEI, the Electric Utility Companies' Nuclear Transportation Group, Atomic Industrial Forum, and ANEC on the DOE implementation of the Nuclear Waste Policy Act. The Task Force is to determine whether the current industry efforts are appropriate and whether changes should be made in the utility industry emphasis on, or resources being applied to, these overview efforts.

Chairman Lloyd, we feel that by performing an effective industry overview effort, we will be better equipped to provide comments and recommendations on the nuclear waste program to Congress, the Administration, our electricity customers and our stockholders. We want to provide the funds for the program, however, we insist that proper controls be provided over its cost and that the schedule is achieved. It is vital that DOE starts taking our spent fuel in 1998.

Nuclear Waste Disposal Program

Our industry worked closely with many Congressional Committees over a period of several years to bring about the enactment of legislation that we know as the Nuclear Waste Policy Act of 1982 (the Act). The utilities accepted their responsibility under the Act by signing contracts with DOE and for the past several months have been providing funds to the Federal

Nuclear Waste Fund at a rate of about $25 million each month. Our concern extends to whether the Congress, the Administration, DOE, the states, and all other parties are upholding their part of the bargain as defined in the language, as well as the spirit, of the Act.

Many compromises were made during the development of this landmark legislation. While many of us would have preferred legislation more to our own particular liking, we accept the legislation as passed and will work to see that it is carried out as effectively and efficiently as possible. We do not believe that any change should be made in the legislation in the near-term. Moreover, due to the legislation's complex nature, it should not be amended ad hoc, but rather only through comprehensive hearings before the relevant committees of jurisdiction.

In terms of its principal elements, the Act prescribes both a process and schedule for carrying out the task of waste management and disposal. The process, of course, is composed of the individual steps necessary for accomplishing waste disposal and achieving the cooperation of all concerned parties, while the schedule sets the timetable for taking those steps and reaching the established goal. Congress did not set a hierarchy with respect to process and procedure; rather the Act treats process and schedule to be of equal importance. It is vital, however, for DOE to begin accepting spent fuel in 1998, and they have stated in the Mission Plan that this will be done.

We are concerned that there are pressured being exerted on the Department of Energy to over-emphasize process at the expense of the schedule established by the Act. This is reflected in a recent draft of the DOE Mission Plan for the waste management program. The draft Mission Plan not only specifically places a priority on process over the schedule prescribed in the Act, but proposes to slip the schedule for achieving significant milestones. For example, the Plan proposes to delay the recommendation to Congress by the President for the first repository site from March 31, 1987--as mandated in the NWPA--to December 1990. This is a delay of almost four full years or three years based on the extension provided in the Act. This length of delay does not appear appropriate or necessary, and specific direction should be provided by Congress to minimize any such delays. Under section 114e, any Federal Agency that is unable to meet a Congressionally mandated schedule is required to report to Congress on the reasons for the delay, and to take steps to mitigate its impact.

Although we support the need to proceed through the process called for in the Act with detailed recognition of all concerns, we do not believe the schedule should be secondary. Having the first repository by 1998 is very important, and many intermediate steps must be achieved on a timely basis for this to happen. DOE should be encouraged to move aggressively to re-establish the schedule to match as closely as possible the dates prescribed in the Act and to reassert its determination to comply with the timetable for reaching future milestones. We will be watching this matter closely and believe that Congress should carefully monitor progress against the backdrop of the timetable as a "vital sign" of the health and condition of the program.

Also, we are concerned, about the special interest pressures that are being brought to bear on DOE to influence the direction of the program in ways other than mandated by Congress. We have observed pressures being applied on DOE to achieve preferences within its Site Selection Guidelines for certain potential host states to gain an advantage that they were unable to gain from Congress. This has resulted in a delay in the issuance of the Guidelines which are needed now.

Other pressures are evident by research organizations to continue the past practice of researching everything, rather than to proceed with a definitive effort to resolve problems of geologic disposal in a timely manner. Contractors are developing the primary programmatic input to the DOE offices with the primary motive apparently being to extract money from the Waste Fund. While the contractors are intimately involved in developing programmatic details, the utilities that are providing the funds often have difficulty in obtaining access to such details until after the plans are in place. We believe the utility industry can make a significant contribution to the overall program by being allowed to participate earlier in the programmatic planning process.

Chairman Lloyd, I would like to consider with you one additional matter pertaining to the Act. That is, the size of the program and how it should be managed. The decentralized approach of DOE management may not be the proper approach to control such a large project. The foresight of Congress in calling for a study to review and evaluate alternative organizational structures for carrying out this enormous task was fortuitous. While the study will be completed later than originally requested, it should be a valuable input to defining the type of organization required to carry out this very large and difficult task.

Stability is essential for the leadership of a successful program and a strong central project control appears to be needed to satisfy all aspects, institutional, political and technical, with good coordination and still achieve a reasonable time schedule with responsible cost control. DOE must be encouraged to resist such things as individual pressures for pet projects, perceived new and better alternatives, desires to research every concern forever and the strong efforts to achieve a preferred position by potential host states.

The Fiscal Year 1985 Budget Request indicates that DOE is planning increases in the one mill per kilowatt hour fee because of an estimated revenue shortfall. Congress, as well as ourselves, need considerably more supporting justification than is contained in the sketchy budget document before an increase should be permitted. Congress anticipated that the revenues would not match the expenses in every year by permitting the program to borrow money from the U.S. Treasury or, in the case of having excess funds, invest in Government securities. The program is to achieve full cost recovery over its life and the fee is to be determined on that basis. The self-imposed requirement of the Administration that the revenues must exceed the expenses in all early years is a burden that does not appear compatible with the legislation.

There are many other aspects of the program that could be discussed; we have touched upon only a few. In fact, we commend the Department of Energy for its substantial accomplishments during the first year of this multi-decade project.

The DOE progress includes:

- Major program changes to address the deliberate process steps of the legislation to overcome the institutional and political barriers.
- A separate Office of Civilian Radioactive Waste Management has been established within DOE and its Director reports to the Secretary.
- Seventy contracts were signed by June 30, 1983 with owners and generators of nuclear waste.
- Monies are being received into a Nuclear Waste Fund at a rate of about $25 million each month.
- Six states have been notified they have potential sites for the first repository and seventeen additional states notified regarding the second repository site.
- Siting guidelines have been prepared and submitted to NRC for concurrence.
- A draft of Volume I of the Mission Plan covering overview and current program plans has been prepared and provided to interested parties for early review and comment.
- Study and design work have been initiated for a Monitored Retrievable Storage (MRS) facility.
- Cooperative agreements have been established with three utilities for development of new on-site storage concepts for spent fuel.

While the pace of DOE efforts may be less than desired, the legislation did establish a very difficult road map and it appears that DOE has been carefully negotiating its way through the mine field for the initial steps of this program. However, the following summarizes several areas of real concern about the program. It may be appropriate to take specific initiatives to assure that they are addressed effectively.

- A permanent Director has not been nominated, and all except one person in the upper level management are designated as in an acting capacity. The assignment of top quality permanent management personnel is necessary to get the task accomplished.
- Establishment of a detailed project plan and decision schedule is essential. A definitive and detailed repository schedule has not been provided that places the necessary emphasis on the critical path items to assure the availability of a repository in 1998. DOE concedes that it will not achieve the selection of the first repository site by 1987 as called for in the Act.
- It appears that a strong, central control project office with substantial control over field activities is needed to assure the effective and efficient control of the program. Such is not the way that DOE performs its normal business activities.
- National Laboratories, academicians, consultants and contractors appear to be spending funds rapidly on time and material, open-ended arrangements. It appears desirable to urge that fixed cost contracts with incentives and penalties be pursued for a majority of the expenditures.
- States are requesting specificity in the Site Selection Guidelines in their effort to obtain a preferred position for their state. Preferences beyond that legislated in the Act must be resisted by DOE and NRC.
- Process and schedule details are provided in the Act and DOE should not place emphasis on one over the other.
- Full cost recovery for the program is essential and any change in the fee being paid into the Nuclear Waste Fund must be based on a detailed evaluation that is fully supported to achieve a balance over the complete program.

Spent Fuel Storage

On a somewhat different subject, Carolina Power & Light Company is negotiating an agreement with the Department of Energy for the demonstration of dry storage of spent nuclear fuel at CP&L's Robinson plant in South Carolina. Three horizontal concrete modules will be constructed as shown in Figure 1. A canister containing seven intact PWR fuel assemblies will be placed in each module. CP&L's IP 300 shipping cask will be used to transfer the fuel bearing canisters from the fuel pool to the dry storage modules. See Figure 2. The demonstration will be funded by CP&L, the Electric Power Research Institute and DOE.

The modular design used in this storage system provides for economic capital investment. The horizontal transfer of the canister eliminates the need for a large nuclear safety grade crane for the dry storage system. The system provides storage of fuel with possible future repository interface benefits due to the canistering of the fuel. Also, the use of canisters that could be placed in any suitably designed transportation cask will demonstrate that storage of spent fuel can be independent of future shipping and transportation requirements and regulations.

The program objectives are to:

- Demonstrate one of the dry storage alternatives
- Determine its performance characteristics
- Benchmark its performance models
- Demonstrate its economics
- Determine the licensability of this storage alternative

- Assist utilities in meeting their own interim irradiated fuel storage requirements at reactor sites
- Develop a vendor and the technology applicable to a large, dry cask
- Demonstrate a fuel storage technique with generic applicability to the nuclear industry

The program is scheduled to begin in early 1984 and continue through 1987. Spent fuel will be loaded during the third quarter of 1986. Data will be gathered during the entire storage period. After six months of storage, one canister will be removed from the module to demonstrate retrieval.

CP&L believes that this program together with others now planned have the potential to permit utilities to avoid using government supplied backup storage until the MRS or repository is available. We are pleased with DOE's support in this program.

Low-Level Waste Disposal

The DOE has had an ongoing program for the past few years addressed to the problems of low-level waste disposal. This program covers a wide variety of low-level wastes of both defense and civilian origin which have many characteristics in common. We have found the participants in this program very cooperative with industry and have enjoyed good working relations with them. This activity does not receive much publicity, low-level wastes are not a very glamorous subject, but the country has benefited from this program and we urge its continued support by this committee. Of particular importance at this time are the activities related to the development of new low-level waste disposal sites in response to the Low-Level Waste Policy Act of 1980. Continued DOE financial and technical assistance in the disposal site selection process is of critical importance.

Regional Compacts

Since passage of the Low-Level Radioactive Waste Policy Act of 1980 (Pub. L. 96-573), EEI, UNWMG and ANEC, and their member companies, have actively participated in the development of regional low-level waste disposal compacts by working with appropriate federal, state and local officials to encourage prompt compact development, providing comments on draft compacts, and testifying before Congress.

We support the concept of state responsibility for low-level radioactive waste disposal, and believe that the LLW Policy Act provides an appropriate mechanism for the implementation of an effective national waste disposal program. Such a program is essential for the orderly conduct of many medical, educational, industrial and other activities in addition to the nuclear generation of electricity. The current regional compacting effort is a crucial step in the process of ensuring that the nation's low-level nuclear waste is disposed of in a safe, environmentally sound, efficient and equitable manner. We urge all of the states to continue their efforts to implement compacts and develop regional facilities, and encourage Congress to take action to approve the regional compacts in an expeditious manner.

The compacts should provide an orderly, systematic and comprehensive mechanism for disposing of the nation's low-level radioactive waste. Disposal of such waste in regional facilities is a matter which transcends state boundaries. Questions involving such issues as the materials to be disposed of a regional facilities, access to those facilities and the respective rights and obligations of party states, non-party states, generators and shippers require a coordinated approach. Thus, a certain degree of uniformity is necessary.

On the other hand, recognition must be given to the particular concerns and problems faced by various regions and states. Absolute uniformity in all aspects of the regional disposal system is neither necessary nor desirable. Thus, it is important that Congress be sensitive to regional and state interests to the extent those interests are consistent with safe, efficient, equitable and environmentally sound low-level radioactive waste disposal practices.

Perhaps the most important issue to be resolved regarding regional compacts is the need to ensure access to existing disposal facilities in the interim period after January 1, 1986, but prior to the time that new regional (or individual state) facilities are in operation. While we are not in favor of a Congressional extension of the January 1, 1986 deadline set forth in the LLW Policy Act, it is vital that there be continued access to waste facilities, on a national basis, to ensure the availability of adequate disposal capacity in that interim period.

We do not believe that the LLW Policy Act contemplated that states or regions would obtain additional regulatory jurisdiction not already authorized by existing federal law except in very limited circumstances. Nor do we believe that the Act was otherwise intended to provide authority for a restructuring of the existing regulatory framework governing the packaging and transportation of low-level nuclear waste, or to otherwise alter the preemptive effect of existing federal law.

While states are involved in the regulation of packaging and transportation activities, such regulation must be consistent and compatible with federal requirements. Variations in packaging and transportation standards could result in a cumbersome system of inter-regional requirements. Such variations could jeopardize the safe and efficient movement of low-level nuclear waste throughout the country, and would place an unnecessary burden on waste generators and shippers by rendering compliance more difficult.

We have a number of specific concerns which relate to particular aspects of the individual compacts. We hope to have the opportunity to air those additional concerns during the Congressional ratification process of the compacts. In any event, We reiterate our basic support for the regional compacts, and urge prompt Congressional consideration and approval.

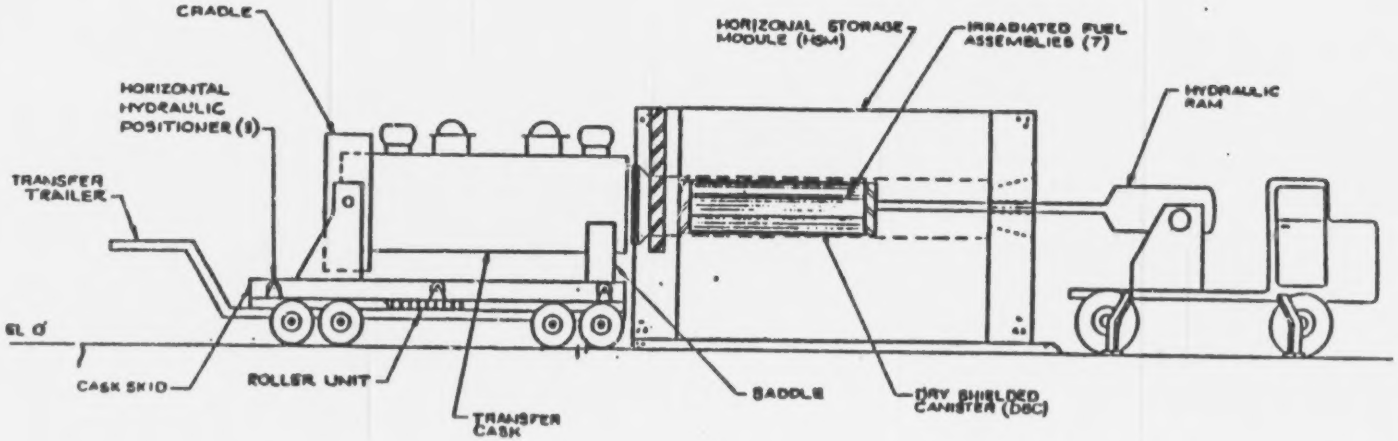

CRADLE
HORIZONTAL HYDRAULIC POSITIONER (1)
TRANSFER TRAILER
EL 0'
CASK SKID
ROLLER UNIT
TRANSFER CASK
HORIZONAL STORAGE MODULE (HSM)
IRRADIATED FUEL ASSEMBLIES (7)
HYDRAULIC RAM
SADDLE
DRY SHIELDED CANISTER (DSC)

Figure 1

Primary Components of the NUHOMS System

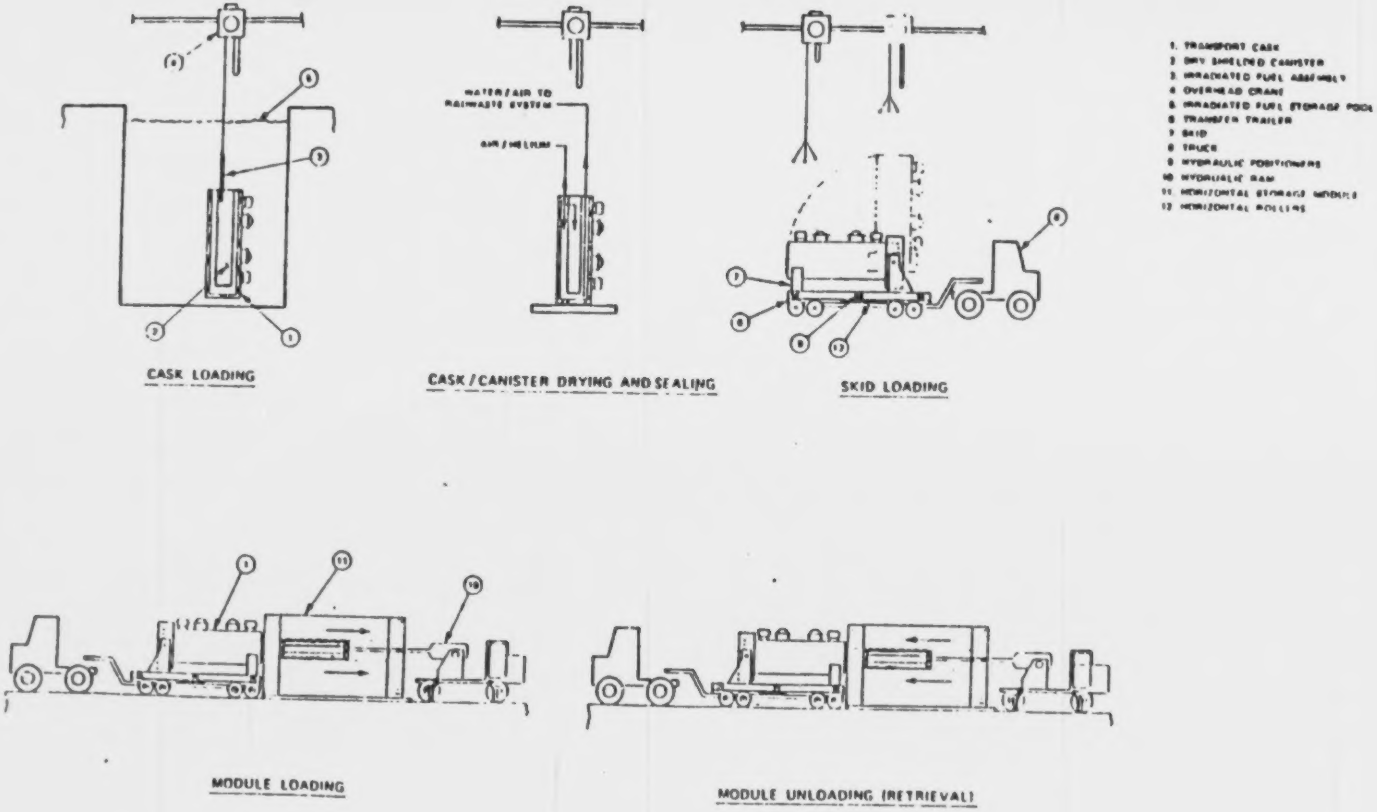

1. TRANSPORT CASK
2 DRY SHIELDED CANISTER
3 IRRADIATED FUEL ASSEMBLY
4 OVERHEAD CRANE
5 IRRADIATED FUEL STORAGE POOL
6 TRANSFER TRAILER
7 SKID
8 TRUCK
9 HYDRAULIC POSITIONERS
10 HYDRAULIC RAM
11 HORIZONTAL STORAGE MODULE
12 HORIZONTAL ROLLERS
WATER/AIR TO RADWASTE SYSTEM
AIR/HELIUM
CASK LOADING
CASK/CANISTER DRYING AND SEALING
SKID LOADING
MODULE LOADING
MODULE UNLOADING (RETRIEVAL)

Figure 2

Material Handling Diagram for NUHOMS System

CONCEPT FOR AN ALL-PURPOSE TRANSPORT, STORAGE, AND DISPOSAL CASK FOR SPENT NUCLEAR FUEL MANAGEMENT

Raymond E. Hoskins
Special Projects Staff
Division of Fuels
Tennessee Valley Authority
Chattanooga, Tennessee
December 12-15, 1983

Today I would like to briefly review where TVA has been in spent nuclear fuel management, where we are today, but mostly I want to talk about the future directions of our spent fuel management activities. We have come to believe that taking a systems approach to overall integration of spent fuel management with respect to onsite storage, transportation, offsite storage, and disposal is essential. Our studies show that development of an integrated dry cask system suitable for onsite storage, transportation, monitored retrievable offsite storage, and perhaps use as a disposal container in a geologic repository offers the potential of the lowest overall economic, environmental, and social cost related to spent fuel management.

Public perceptions related to transportation, as well as technician and economic considerations, have been major factors in shaping TVA spent fuel management activities. From a transportation standpoint we believe:

1. It is desirable to avoid unnecessary handling and shipment of spent fuel,
2. The number of shipments should be minimized, and
3. Spent fuel shipments should be kept off the public highways to the extent practical.

The Nuclear Waste Policy Act of 1982 (NWPA) clarifies responsibilities, sets out procedure requirements, provides financial means, and sets goals that make it possible to get the job done. It, however, does not give any guarantees or provide remedies if the Government fails to perform beyond increasing the fee to pay what it may eventually cost. We believe a concerted cooperative effort among the Government, nuclear utilities, and industry will be required rather than a fragmented approach with high hopes that things will somehow work out. (We hope the NWPA does not become known as the Nuclear-WPA.) The present contractual provisions between the Government and utilities do not encourage effective integration of spent fuel management. Some mechanism must be found that will provide the incentives necessary to encourage realization of the potential savings related to integrated spent fuel management.

In the mid-1970s when it became apparent that there would be extended delays in reprocessing spent nuclear fuel, TVA began expanding in-plant fuel storage capacity. In 1979 we completed a comprehensive study of storage alternatives and concluded:

1. It was desirable to utilize existing plant storage pools to the extent practical.

2. We should be prepared to provide for onsite storage for as long as necessary until the U.S. Government provides for disposition of the spent fuel.

3. It was desirable to develop passive dry storage systems as alternatives to building new pool storage facilities.

Since that time we have expanded in-plant storage capacity using high density storage racks, sponsored or participated in conceptual design studies of dry storage concepts, including vaults, silos, casks, and drywells, and are carrying out cooperative activities with the Department of Energy (DOE) and others to demonstrate rod consolidation and cask dry storage at the Browns Ferry Nuclear Plant. In these demonstrations, TVA is generally responsible for the onsite work and site-specific regulatory requirements. The other participants are supplying equipment and providing generic licensing and technical support. We have also undertaken an evaluation of alternatives to choose the future direction of TVA's spent fuel management activities.

Our cask dry storage demonstration will use two casks in a licensed nominal 2-year demonstration, after which the fuel will be returned to the reactor pool and the casks returned to their owner. A Gesellschaft fur Nuklear Service (GNS) Castor 1C cask, on loan from the Federal Republic of Germany utility Preussenelektra, represents the established state of the art in cask dry storage technology sponsored by the German electric utility industry to meet its specific needs. This cask is licensed for storage and transportation in Europe. It is made from nodular (ductile) cast iron and has a storage capacity of about 3 metric tons of unconsolidated, 1-year-old fuel assemblies. GNS's topical report was submitted in May of 1982 and is well along in the NRC review process. In addition to the GNS cask, DOE purchased a Ridihalgh, Eggers, and Associates (REA) 2023 cask for this demonstration. This is a new cask design which has a capacity of about

10 tons of unconsolidated, 5-year-old fuel. It is of conventional stainless steel/lead construction similar to transportation casks and is designed to be transportable with a special overpack. The REA topical report was submitted to NRC in May 1983 and has started through NRC review.

These casks were shipped to Allied General Nuclear Service's (AGNS) Barnwell plant where handling procedures have been developed by DOE. We are presently preparing the storage facility license application based on the GNS cask design and plan to submit it to NRC early next year. Fuel loading into the GNS cask is anticipated sometime late in 1984 but is dependent upon NRC license review. The demonstration storage facility (fenced concrete pad inside existing security) is being designed to accommodate both casks. We plan to amend the license to include the REA cask when their topical report is approved.

The rod consolidation equipment is an adaptation of a design by the Nuclear Assurance Corporation that was developed through a DOE cold demonstration at the AGNS plant. Twelve BWR fuel assemblies will be consolidated. The equipment has been fabricated and has gone through a cold checkout at AGNS and is ready for installation at Browns Ferry. We expect to perform the consolidation in 1984 contingent upon working it into the plant's O&M schedule. Since no unresolved safety issues were identified for this limited demonstration, no formal licensing action was required.

In preparing to analyze a large number of diverse alternatives, we decided to use probabilistic evaluation methods due to the many uncertainties involved. To make sure that all factors were considered, the analysis is based on full life cycle cost, including decommissioning of storage facilities, spent fuel shipment, monitored retrievable storage (MRS) if necessary, and disposal. This permits tradeoffs between these sectors to reduce overall costs to TVA's ratepayers. When we started developing this procedure, we assumed TVA would be responsible for all aspects of spent fuel management through delivery of high-level waste to the DOE repository. With passage of the NWPA, the scope of our direct responsibility was essentially limited to onsite storage; however, it continues to be appropriate to consider the overall cost to our ratepayers. Since there is broad interest in this problem and the data needed to do this analysis, we have undertaken a cooperative effort with the Electric Power Research Institute (EPRI) whereby TVA is doing the model development and an EPRI contractor (Boeing Engineering & Construction Company) is developing normalized generic cost data for the various storage concepts.

How much spent fuel a plant will produce over its lifetime and when DOE will actually accept spent fuel at a rate greater than the rate at which it is being produced are the major factors which will determine how much spent fuel storage capacity a utility will need. These are subject to considerable uncertainty. Uncertainty can be described in terms of probabilities, taking into account the multitude of factors that affect these parameters. A subjective assessment of these factors is shown in table 1. These were developed by encoding the judgments of several people knowledgeable in the factors that will affect the outcome. From this assessment we see that there is very little possibility that DOE will be accepting fuel on a large scale before the turn of the century, there is a

Table 1 Subjective Assessment of Major Uncertainties that Affect Utility Spent Fuel Storage Needs

Cumulative Probability (%)	DOE Acceptance (Date)	Nuclear Plant Nominal Life (Years)
0.1	1998	9
10.0	2001	21
25.0	2004	27
50.0	2008	33
80.0	2013	42
90.0	2017	47
99.9	2030	70

50/50 chance that they will by 2008, and there is a 10-percent chance it may be after 2017. The useful service life of a nuclear plant is the principal indicator of how much spent fuel it will produce. It is seen that the expected life falls well within the 30 to 40 years generally used for financial purposes.

However, this distribution recognizes the possibility that it may be significantly shorter or substantially longer which would make a large difference in the amount of spent fuel storage that will be needed. At this time we do not and cannot definitely know the outcome. We can only take these uncertainties into account by planning to provide the flexibility necessary to deal with them as the future is revealed.

The effects of these uncertainties on the spent fuel storage needs of TVA's Sequoyah Nuclear Plant is illustrated in figure 1. Sequoyah is a two-unit PWR that began commercial operation in 1981, has high density storage racks, and is the TVA plant with the earliest potential need for additional storage. While there are plants that have earlier needs and plants that have later needs, Sequoyah is probably representative of the typical industry situation.

The cumulative spent fuel discharges versus time are plotted in figure 1 for the 10-, 50-, and 90-percent probability level that the actual discharges will be equal to or less than the indicated amount. It is seen that beyond the year 2000 there is great uncertainty in spent fuel discharges. Superimposed over these are two horizontal lines that indicate plant storage capacity with and without expanding in-plant storage capacity

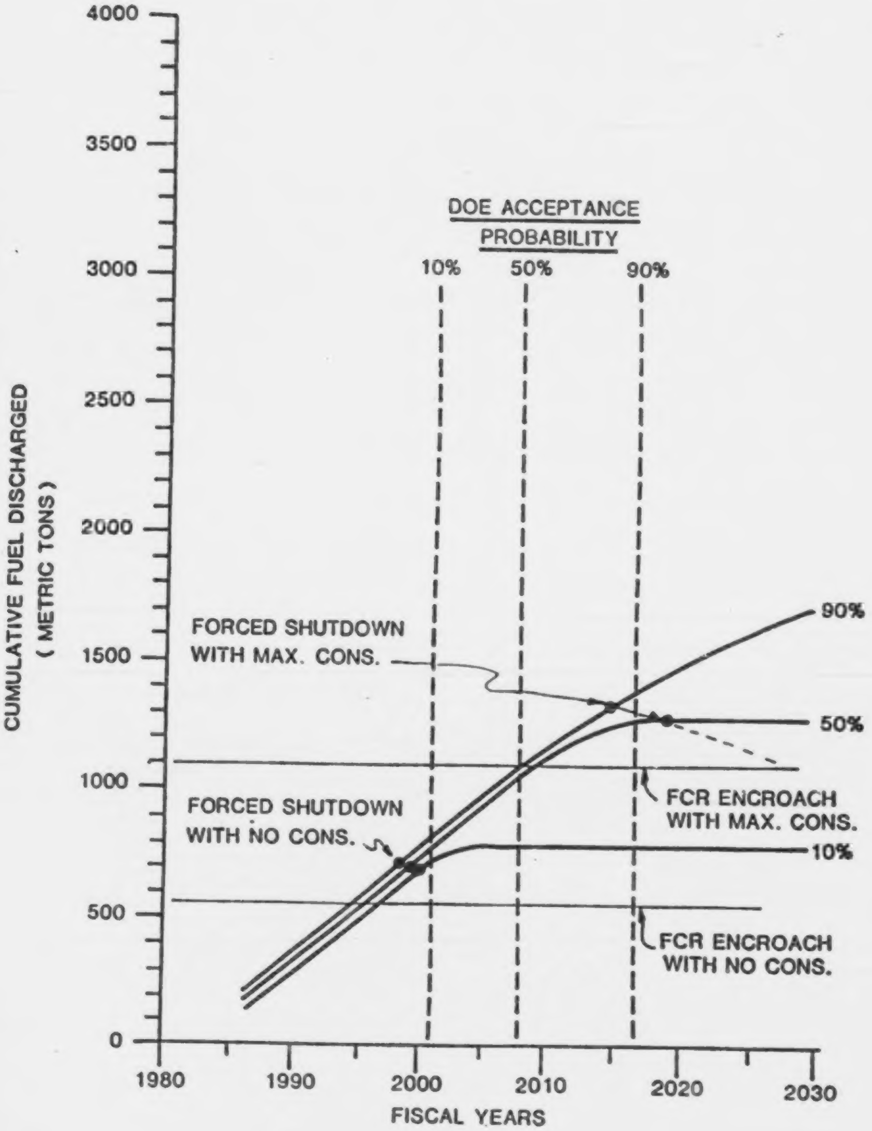


Fig. 1 Reference Nuclear Plant
Probabilistic Spent Fuel
Storage Requirements Forecast

through rod consolidation or other means. Uncertainty in when DOE will begin receiving the fuel is also shown. This figure illustrates the bounds for planning spent fuel management for TVA's Sequoyah plant.

For Sequoyah, we see from figure 1 that there is a 10-percent chance or probability that we will encroach on full core reserve (FCR) and will need additional storage by mid-1994, a 50-percent chance that we will need additional storage by the middle of 1995, and a 90-percent certainty that additional storage will be needed by 1997 based on present plans. If we did nothing at Sequoyah, there is a 10-percent chance that the plant would be forced to shut down by 1997, 50-percent chance by mid-1998, and a 90-percent chance by mid-1999. If one were 100 percent certain that DOE would meet our needs by 1998, there is about a 50-percent chance that we might get by without doing anything. Considering the uncertainty of when DOE will actually take TVA's fuel, as well as the uncertainty in how much spent fuel we will produce, we expect to need additional onsite storage of about 532 metric tons. There is, however, about a 10-percent chance that our storage needs could be as little as 240 or as much as 725 tons. If we increase the effective storage capacity through rod consolidation or other means by a factor of 2, then the expected additional onsite storage requirements are reduced to 33 tons. There would, in this circumstance, be about a 70-percent probability that no additional storage would be needed. However, on the high side there is still a 10-percent chance that requirements could be as large as 175 tons.

The results for all TVA plants are shown in table 2. From this we can see that there is similar uncertainty in how much additional storage capacity we might need at each plant. If we were to expand storage in existing pools through rod consolidation or other means, the amount of additional storage needs is greatly reduced and would be deferred beyond the turn of the century. I would like to call your attention in particular to the column indicating the Expected Additional Storage Duration. This includes the time it will take DOE to work off the backlog of fuel once they are able to start shipping fuel at the nominal production rate. It is seen that we can expect to have this fuel in storage for some time. TVA does not have a particularly pressing spent fuel storage problem and we can afford to take a long-term view of developing the most effective means for dealing with the large-scale spent fuel management problems of the 1990s when our and most other utility needs will materialize.

These probabilistic methods provide some valuable insights into economic and technological risks, as well as placing a value on flexibility, when it is necessary to make decisions under uncertainty. Perhaps the greatest value of this methodology is that it requires a systematic examination of the problem and permits a quantitative measure of relative risk.

Preliminary findings from our analysis indicate that the potential value of developing an integrated cask dry storage system can justify the effort. The potential saving related to reduction in fuel handling and using the same cask for storage and transportation is apparent. There could also be significant savings in reducing the number of shipments, as well as using the cask as a disposal container. Cask storage could also serve as an MRS

Table 2 TVA Spent Fuel Storage Needs

	10% Prob. Full Core Reserve Encroachment (Fiscal Yr.)	Additional Spent Fuel Storage Needs (Metric Tons): 10% Prob. Less Than	Additional Spent Fuel Storage Needs (Metric Tons): Expected Value	Additional Spent Fuel Storage Needs (Metric Tons): 10% Prob. Greater Than	Expected Additional Storage Duration (Years)
With No Consolidation					
Sequoyah	1994.5	230	532	725	25
Watts Bar	1997.5	160	333	640	19
Browns Ferry	1999.0	0	371	650	12
Bellefonte	2009.0	0	35	200	2
With Full (2.0) Consolidation					
Sequoyah	2008.5	0	33	175	3
Watts Bar	2010.5	0	19	130	1
Browns Ferry	Never	0	0	0	0
Bellefonte	Never	0	0	0	0

facility if one should be needed either for temporary storage or as a primary repository if the geologic repository is delayed. The use of the same cask at the reactor site and at the MRS facility does not encumber other options. By taking an overall systems approach, it appears possible and desirable to develop an integrated cask system suitable for storage, transportation, and disposal with no compromise in safety. In such a system, once the fuel is placed in the cask at the reactor, it would never be removed unless a decision is made to reprocess the fuel (then the container could be reused for the reprocessing plant waste disposal). Preliminary engineering studies indicate that self-shielding repository waste packages appear to be an attractive option for repository design. These self-shielding waste packages are very similar to dry storage casks. TVA, in cooperation with the Edison Electric Institute, is sponsoring a preliminary technical and economic study of the universal package concept, which should be completed by Westinghouse early in 1984.

Figure 2 schematically illustrates the current technology reference case for managing spent fuel using auxiliary pools for onsite storage, shipment by truck to an MRS or geologic repository, use of drywell storage at an MRS if one should be required, and disposal of canned consolidated fuel in a repository bore hole. This concept would require several special facilities and would involve repackaging or handling the spent fuel several times. For comparison, figure 3 depicts the use of large casks with unconsolidated fuel for onsite storage, transportation, and storage at an MRS. Facilities and handling requirements onsite and at an MRS would be greatly reduced. Operations at a repository, however, would not be affected since the fuel would still need to be consolidated, canned, and

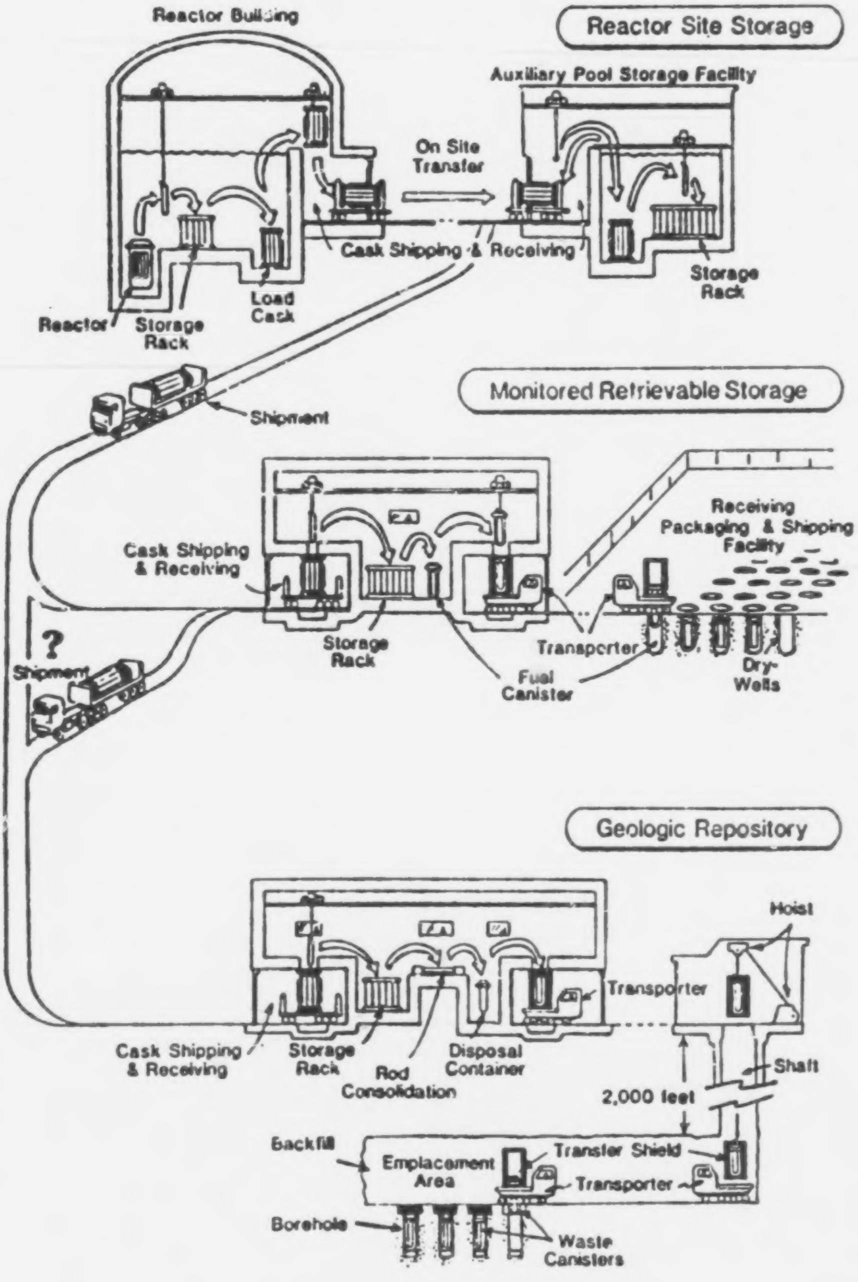

Reactor Building
Reactor Site Storage
Auxiliary Pool Storage Facility
On Site Transfer
Cask Shipping & Receiving
Storage Rack
Reactor
Storage Rack
Load Cask
Shipment
Monitored Retrievable Storage
Receiving Packaging & Shipping Facility
Cask Shipping & Receiving
Storage Rack
Transporter
Fuel Canister
Dry-Wells
?
Shipment
Geologic Repository
Hoist
Transporter
Cask Shipping & Receiving
Storage Rack
Rod Consolidation
Disposal Container
Shaft
2,000 feet
Backfill
Emplacement Area
Transfer Shield
Transporter
Borehole
Waste Canisters

Fig. 2 Spent Nuclear Fuel Management Reference Case

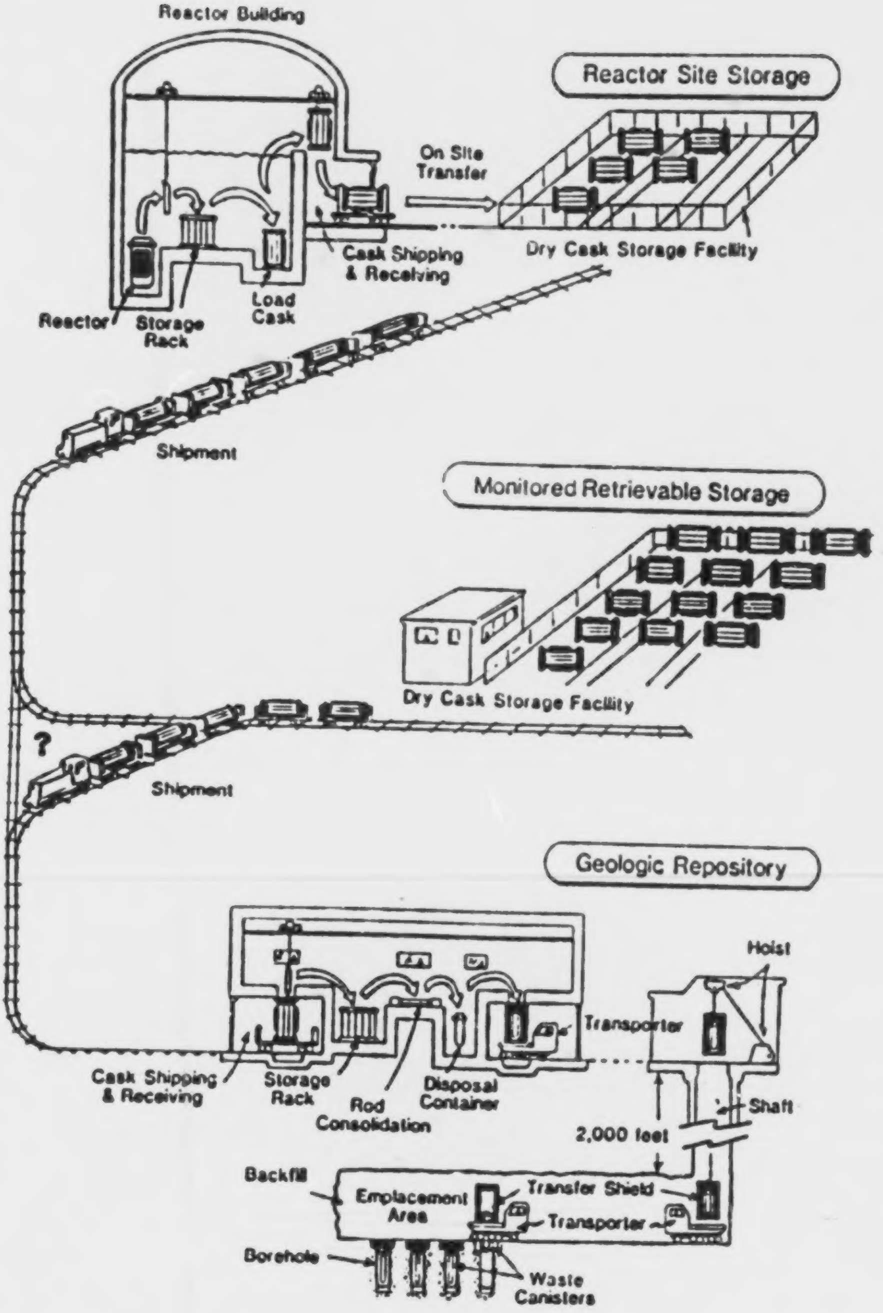

Reactor Building
Reactor Site Storage
On Site Transfer
Cask Shipping & Receiving
Dry Cask Storage Facility
Reactor
Storage Rack
Load Cask
Shipment
Monitored Retrievable Storage
Dry Cask Storage Facility
?
Shipment
Geologic Repository
Hoist
Transporter
Cask Shipping & Receiving
Storage Rack
Rod Consolidation
Disposal Container
Shaft
2,000 feet
Backfill
Emplacement Area
Transfer Shield
Transporter
Borehole
Waste Canisters

Fig. 3 Spent Nuclear Fuel Management
Integrated Storage/Transport Cask Design

placed in a bore hole in the repository. Figure 4 depicts the universal cask concept where fuel would be consolidated at the power plant before it is placed in the cask and the cask would ultimately be placed in the repository, eliminating much of the surface operations at the repository. It also appears that, except for problems related to handling the heavier package, repository design could be simplified by use of a self-shielding package. Once a dedicated cask is assigned to spent fuel, the usual economic considerations in spent fuel transportation and logistics are no longer applicable, thus permitting the use of unit trains, barge, or other transportation options where turn-around time and equipment utilization are less important.

In order to examine the potential benefits of developing integrated cask storage systems, we have carried out a preliminary study of alternative cask designs based on the needs of our Sequoyah plant. The decision flow network used for comparing conventional pool storage and various cask design alternatives is shown in figure 5. While there are many other possibilities, these 11 cases serve to examine the range of interest. In the decision tree, the first choice is whether or not to consolidate fuel. If we choose not to consolidate then our choices are to provide additional pool storage or use dry cask with unconsolidated fuel for which we have several choices of cask size and use. The nomenclature used to describe the scope of cask use is: ST for storage, ST/TR for storage and transportation, and ST/TR/DS for storage, transportation, and disposal. The 3-ton unconsolidated cask represents the GNS Castor 1C technology, and the 10-ton cask would correspond to the REA cask technology both of which we hope to have successfully demonstrated in a few years. Both of these casks can potentially be licensed for shipment. Ten tons of unconsolidated

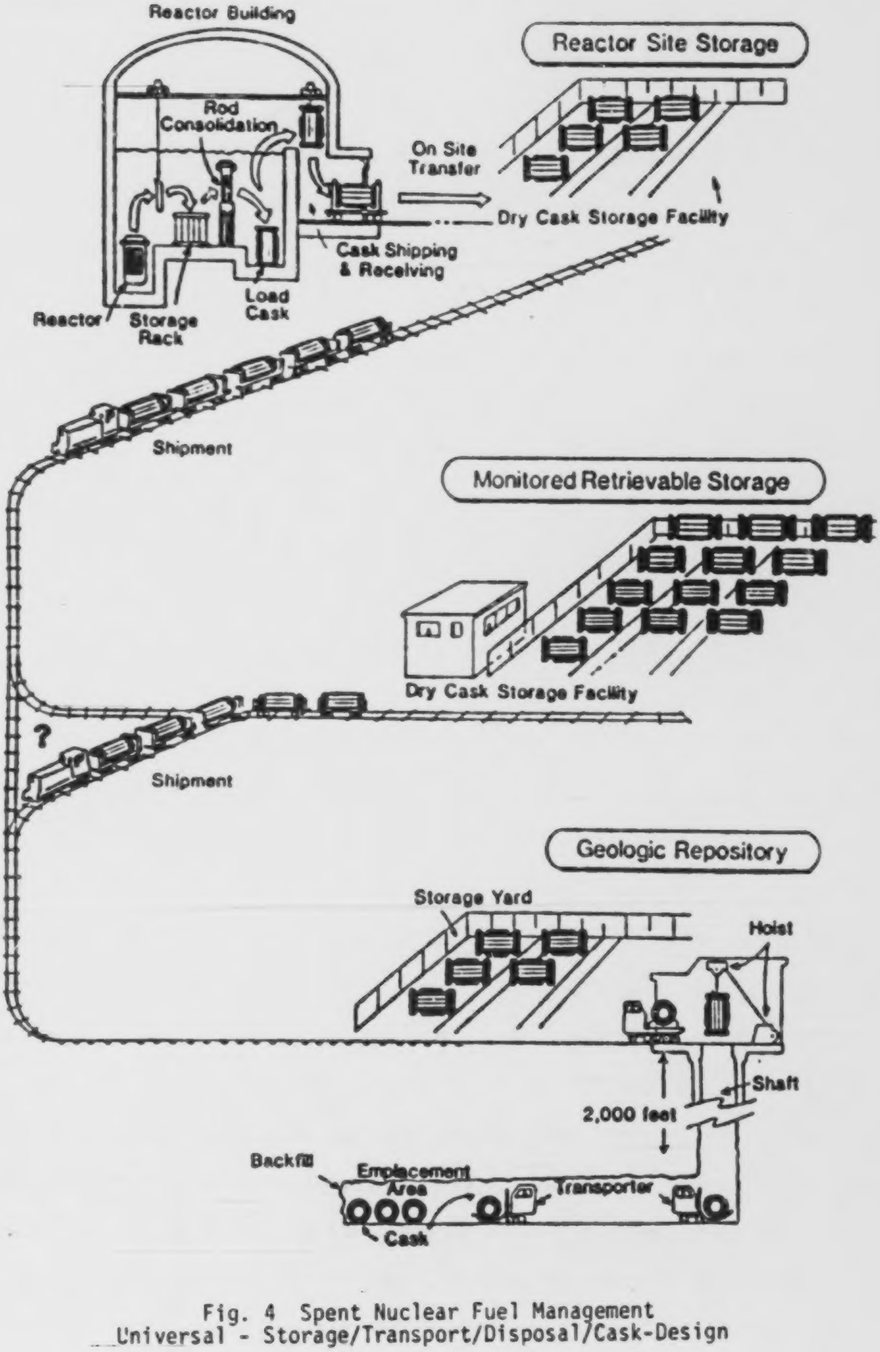

Reactor Building
Reactor Site Storage
Rod Consolidation
On Site Transfer
Dry Cask Storage Facility
Cask Shipping & Receiving
Load Cask
Reactor
Storage Rack
Shipment
Monitored Retrievable Storage
Dry Cask Storage Facility
?
Shipment
Geologic Repository
Storage Yard
Hoist
Shaft
2,000 feet
Backfill
Emplacement Area
Transporter
Cask

Fig. 4 Spent Nuclear Fuel Management
Universal - Storage/Transport/Disposal/Cask-Design

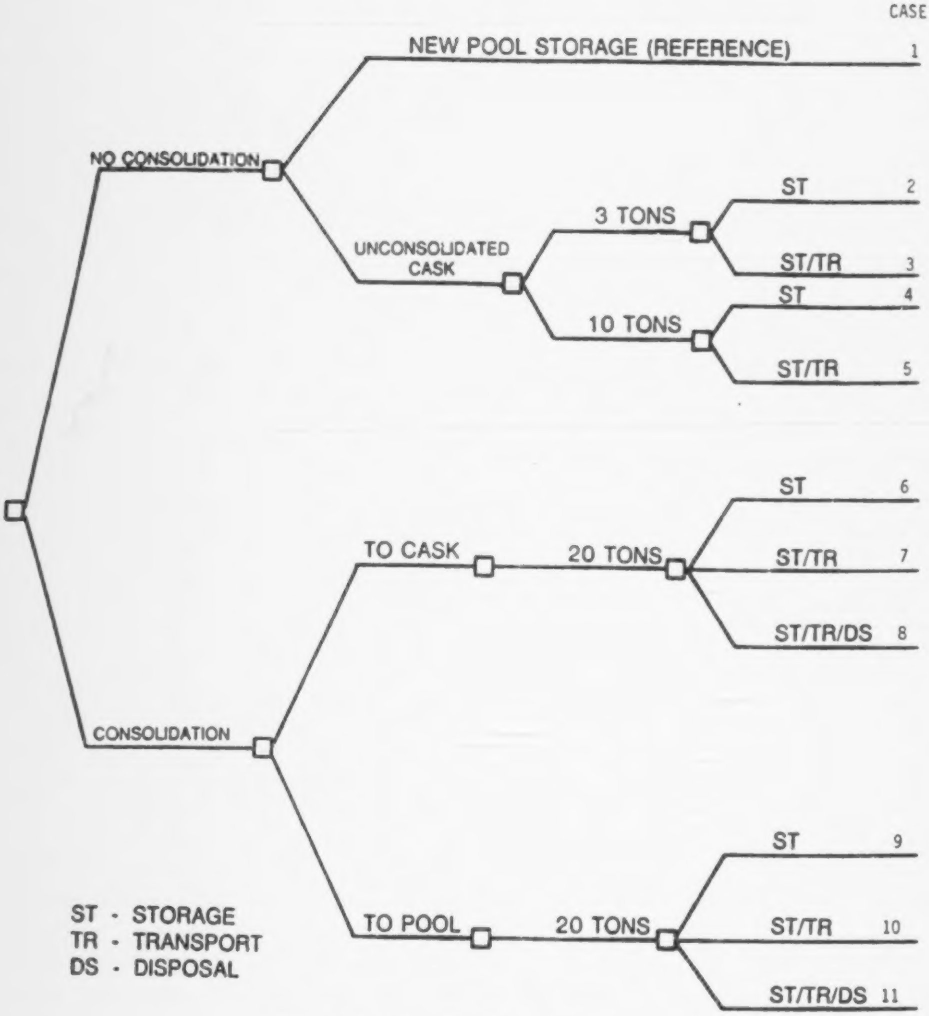

CASE
NEW POOL STORAGE (REFERENCE) 1
NO CONSOLIDATION
UNCONSOLIDATED CASK
3 TONS
ST 2
ST/TR 3
10 TONS
ST 4
ST/TR 5
CONSOLIDATION
TO CASK
20 TONS
ST 6
ST/TR 7
ST/TR/DS 8
TO POOL
20 TONS
ST 9
ST/TR 10
ST/TR/DS 11
ST - STORAGE
TR - TRANSPORT
DS - DISPOSAL

Fig. 5 Decision Flow Network of Integrated Cask Storage System

fuel is about the practical handling limit of dry cask capacity which would have a hook weight of about 100 tons, loaded. However, with consolidated fuel that is 10 years old, it appears feasible to get about 20 tons of fuel in a cask weighing about 100 tons, loaded. Therefore, for simplicity we only consider the larger cask in examining the potential for the three use options with consolidated fuel. The principal difference in the two consolidation branches is whether the fuel is consolidated and placed directly in a cask which is then stored onsite or whether the fuel is consolidated and placed back in the pool storage racks until it is necessary to make room for more discharged fuel.

The results of an economic analysis of these alternatives for the expected conditions previously described for TVA's Sequoyah Nuclear Plant are shown in table 3. The pool storage option, case 1, is used as a base. Results are presented in terms of present worth of saving in 1983 dollars over this option. The total cost of spent fuel management is considered and is divided into onsite cost which will be paid directly by utilities and offsite cost which is within DOE's scope of responsibility but will be paid by utilities through the mill per kWh waste fund fee. The total cost will of course be paid by the ratepayers and its reduction is unquestionably the appropriate overall objective.

The smallest capacity storage cask technology will save about $25 to $30 million over pool storage. While investment costs are higher for these casks, this disadvantage is more than overcome by the large operating cost

Table 3 Potential Savings Related to Development of Integrated Cask Dry Storage Systems for TVA's Sequoyah Nuclear Plant (Millions of Present Worth 1983 Dollars)[a]

Case	Additional Storage Alternative	Onsite Cost			Offsite Cost			Grand Total
		Facilities	Operations	Total	Shipment	Disposal	Total	
1	New Pool	Base[b]	Base	Base	Base	Base	Base	Base
	Unconsolidated to Cask							
2	3-Ton ST	-6.5	32.0	25.5	0.0	0.0	0.0	25.5
3	3-Ton ST/TR	-6.5	32.2	25.7	2.8	0.0	2.8	28.5
4	10-Ton ST	17.7	38.3	56.0	0.0	0.0	0.0	56.0
5	10-Ton ST/TR	17.7	38.4	56.1	11.6	0.7	12.3	68.4
	Consolidated to Cask[b]							
6	20-Ton ST	26.5	25.5	52.0	3.0	0.0	3.0	55.0
7	20-Ton ST/TR	26.5	25.7	52.2	13.4	9.0	22.4	74.6
8	20-Ton ST/TR/DS	21.1	25.7	46.8	13.4	31.1	44.5	91.3
	Consolidate to Pool							
9	20-Ton ST	38.5	27.8	66.3	2.8	0.0	2.8	69.1
10	20-Ton ST/TR	38.5	27.9	66.4	12.2	9.0	21.2	87.6
11	20-Ton ST/TR/DS[c]	38.5	27.9	66.4	12.2	17.1	29.3	95.7

a. Based on a 3.5 point differental between inflation and discount rates.
b. Fuel is consolidated and placed in the cask rather than back in the pool storage racks.
c. In this case DOE pays for all of the casks since more are needed for onsite storage.

saving for passive cask storage systems. Except for some modest transportation savings in the transportable cask case, DOE's costs are not affected.

With the larger unconsolidated cask, utility savings are more than doubled, and DOE's transportation savings are of increasing importance in the transportable cask. Potential savings to the ratepayer are quite significant for development of large casks, especially casks that are transportable.

The potential total savings resulting from further expanding cask capacity to 20 tons by consolidation is not large if use of such casks is limited to storage. However, if the cask can also be used for transportation, the total savings is increased to the range of $75 to $87 million which justifies development of this level of technology. This additional saving is, however, in DOE's scope and would require some form of credits to utilities if the saving is to be realized.

The largest overall saving is for the universal cask cases which range from about $91 million for consolidation directly to cask to about $96 million for consolidation to the pools. In the former case, the savings are about equally shared by the utility and DOE. The case with the greatest saving is for consolidation to the pool, most of which would be realized by the utility since they would not need to buy any casks. DOE's cost would be increased since they must buy all the casks in this case, but somewhat later.

With a potential saving to our ratepayers in the order of $100 million for Sequoyah, TVA's overall savings on all our nuclear plants could be one-quarter to one-half billion dollars. On a national basis, potential savings could be 10 times greater than TVA's savings. We believe this is sufficient incentive to pursue development of integrated cask storage systems. We believe it is extremely important to encourage DOE to take an integrated systems approach to spent fuel management in cooperation with the nuclear utilities. A fragmented approach where each activity is considered essentially independent of the other will continually increase cost and result in ineffective performance.

Economic cost and technical feasibility, however, are not the only considerations that should be taken into account in choosing the future course of spent fuel management. We have, in cooperation with EPRI, undertaken to extend the Sequoyah plant analysis to include environmental, health and safety, and socioeconomic impacts, as well as public perceptions. This work is being done using EPRI's Technological Choice Multiattribute Decision Analysis Model. We have undertaken to identify the differences in important attributes for the 11 cases considered from the time the fuel is discharged from the reactor until it has been placed in a repository. Our analysis of the usual environmental considerations such as land use, air and water quality, endangered species, etc., show no significant difference in these attributes. The attributes for which we could identify potentially meaningful differences are summarized in table 4 on a normalized basis. A magnitude of one is assigned the lowest quantity for a particular attribute, and the others are shown in relative magnitudes. When weighted with the appropriate values placed on each attribute, the alternative with the lowest overall score would in theory be

Table 4 Comparison of Normalized Attributes of the Alternatives Considered in Dry Cask Systems Study for the Sequoyah Nuclear Plant

		Economic Costs		Radiological Dose Commitments[a]			
Case	Additional Storage Alternatives[b]	Utility Onsite	Total Ratepayer[c]	Occupational	Public	Time to Passive Management	Number of Shipments
1	New Pool	6.1	1.6	5.9	6.4	2.1	6.6
	Unconsolidated to Cask						
2	3-Ton ST	4.2	1.4	2.2	6.4	1	6.6
3	3-Ton ST/TR	4.2	1.4	1.8	6.4	1	6.6
4	10-Ton ST	1.8	1.2	1.8	6.4	1	6.6
5	10-Ton ST/TR	1.8	1.2	1	1.9	1	2.0
	Consolidated to Cask						
6	20-Ton ST	2.1	1.2	1.7	3.3	1	3.3
7	20-Ton ST/TR	2.1	1.1	1.5	1	1	1
8	20-Ton ST/TR/DS	2.5	1	1.4	1	1	1
	Consolidated to Pool						
9	20-Ton ST	1	1.2	5.3	3.3	2.1	3.3
10	20-Ton ST/TR	1	1	5.1	1	2.1	1
11	20-Ton ST/TR/DS	1	1	5.0	1	2.1	1

a. Actual total occupational doses are 1 - 2 orders of magnitude higher than total public doses.
b. Cases 1, 2, 4, 6, and 9 assume a 3-ton cask is used for transport.
c. Actual total costs are in order of magnitude higher than utility costs.

the best. We plan to conduct some experiments in encoding public perceptions related to these values. For the present it is sufficient to simply compare the relative magnitudes of the various attributes for the 11 cases.

From an economic cost standpoint, the preference is clearly toward large casks with consolidated fuel. There is not much difference in total cost whether consolidated to casks or consolidated to pools. However, radiological dose commitments favor consolidation to casks, particularly from an occupational standpoint which is strongly related to active storage and fuel-handling operations. Public radiological dose commitment is almost directly related to the number of shipments. The number of shipments required is directly related to cask capacity. The new pool and the consolidated to pool cases delay the time until fuel is secured in some passive storage or disposal mode. Our experience thus far with public perceptions indicates that they are most concerned about spent fuel shipment and would prefer to delay shipment until necessary or until final disposal is available.

In closing I would like to say that we believe there is sufficient potential to pursue development of integrated cask storage systems. It is our intent to seek cooperation with DOE, EPRI, and others in pursuing this goal.

Mr. **Valentine.** Mr. Smith, I want to thank you again for coming here today. I think you make a great contribution to this effort and we, of course, are interested in your judgment. I would like to ask you a series of questions, mainly to emphasize some of the things that you have already addressed. One important phase of this hearing is to be sure that we have an adequate record and that we have underscored and stressed some things that this subcommittee is particularly interested in.

The budget books talk about escalating the 1-mill-per-kilowatthour charge to account for inflation. When we considered this issue, the 1-mill charge was supposedly quite generous. Do you believe DOE is now doing enough to insure cost control for this program?

Mr. **Smith.** Mr. Valentine, there has been no demonstration by the Department of Energy at this time to those interested parties that they do have a firm cost control system in place. I think that until such a cost control system is forthcoming from the Department, one certainly could not answer that question in the affirmative.

By the same token, it is our hope and our expectation that DOE would share the same sentiments that we expressed. We are waiting for this to be forthcoming. I think it underscores the need for the nomination of a permanent director so that that individual may get into office and develop these firm guidelines that I have addressed earlier.

Mr. **Valentine.** Mr. Smith, do you believe that DOE has a statutory authority to escalate this fee without notice to Congress of such or each escalation?

Mr. **Smith.** No, Mr. Valentine, I believe the law deals with that and requires the Department of Energy to make reports regularly and that before any change in the fee could be implemented that it must be submitted to Congress and I believe that there is a period of perhaps 90 days before such a fee could go into effect. It is not necessary, as the law is now written, that Congress actually approve specifically a change in the fee, but I think certainly the spirit of the law is that the fee should not be increased until the material has been submitted to Congress and Congress has had an opportunity to evaluate it and respond and express its opinion.

Mr. **Valentine.** We are talking about just the escalation to cover inflation.

Mr. **Smith.** I don't believe there is any escalation to cover inflation. I would go back and look at the law. If there is no specific provision for escalation to cover the fee in the law, as I think there is not, then I do not think that DOE is authorized to increase the fee for escalation without notifying Congress and without giving Congress an opportunity to evaluate it and comment and act.

Mr. **Valentine.** Do you believe, Sherwood, that a utility auditing right over the program would be helpful in assuring that DOE exercises approximate cost control?

Mr. **Smith.** Yes, sir, I certainly would, and I am not speaking of auditing in the traditional sense of simply checking the invoice to see that the invoice correctly matches up with the work that was done. I am talking about auditing in a broader program review sense that preferably would occur before the expenditures are authorized. So, I am thinking more of a performance review type activity which our industry, on behalf of our millions and millions of customers, would be prepared to do and would be very anxious to do.

Mr. **Valentine**. Do you have an opinion, Mr. Smith, that you would care to express to us as to whether or not the utility industry should be provided with a credit for conducting nuclear waste research and development so as to lower costs for disposal?

Mr. **Smith**. That was discussed at length during and after the congressional consideration of the Nuclear Waste Policy Act of 1982. The decision was made by Congress at that time, as reflected in the law, that no provision should be made for credits. The, I would say, certainly the majority view seemed to be that it was very important to have a standard fixed fee that provided, with certainty, a knowledge of exactly what the costs would be. If one gets into credits, it could be very difficult to provide for in legislation because you could have a credit based upon distance from the repository site. What would your transportation charge? You might have a credit requested because a utility consolidated the fuel, compacted it, and made it easier to handle. You might have a credit requested for some other reason.

I do think that even though there is no provision for credit in the law, that it is possible under the contractual framework by which the Department of Energy and the individual electric utilities negotiate their arrangements for those individual contracts to provide for credits; so that if a utility system spent funds on its fuel, those funds came from its ratepayers, which actually reduced the cost to the Department of Energy of handling its spent fuel, then that contract between DOE and the utility could make some provision for it. I think that is a preferable way to encourage DOE to consider that as a matter for perhaps contracts with individual users, but that the fee itself should be a flat fixed fee of 1 mill.

Mr. **Valentine**. What about credits for reprocessing spent fuel?

Mr. **Smith**. Well, Mr. Valentine, a number of people in our industry, myself included, for many years have felt that it was important that our country proceed with reprocessing. The decision by the country has been to delay any activity in the area of reprocessing. I think that that, from my own personal point of view, is not a wise decision in terms of our needs or in terms of our international position vis-a-vis other countries using nuclear power. Be that as it may, that is the situaiton today. There is no plan nor any undertaking which would lead to reprocessing, and so I would think that it would be premature to consider now whether, and if so, what sort of credit might be made available for reprocessing.

I think that if we move into reprocessing in this country, and it becomes available, and a utility spends money to reprocess its fuel and that, in turn, reduces the DOE cost, then that is something that in the contract between DOE and the utility certainly should be taken into account.

In my working lifetime, I am afraid that I do not believe, personally, that we will be reprocessing spent fuel in this country, and I think that not only is it a disappointment to me personally, but I don't think that is the best course of action for the country to follow, but I think it is a realistic assessment of where we are.

Mr. VALENTINE. How long have you been chief executive officer of CP&L?

Mr. SMITH. Since 1979, 4 years.

Mr. VALENTINE. You were general counsel.

Mr. SMITH. For a number of years, and then president and then chairman and chief executive officer in 1979.

Mr. VALENTINE. Do you believe, Mr. Smith, that the decontamination and decommissioning effort at Shippingport, do you believe this would provide useful information for the utility industry?

Mr. SMITH. Well, it certainly could provide useful information for the utility industry. Our own company, along with Duke Power Co., Virginia Electric & Power Co., and South Carolina Electric & Gas constructed a small prototype reactor at Pharr Shouls, S.C., in the late 1950's. That unit has been decommissioned and it is sitting there safely and securely guarded. There has been no difficulty. What I understand would be proposed at Shippingport is that we would go further and that the components actually would be dismantled and they would be moved to another location for storage.

I think that certainly as we look toward the ultimate decommissioning of many units, to the year 2000 and beyond, that anything that is developed at the Shippingport experience could be of use, yes, sir.

Mr. VALENTINE. Does EEI support the development of the universal spent fuel container, that is, one for storage and transportation as well as disposal?

Mr. SMITH. We have supported that as a sort of nonexclusive way of proceeding. We think the whole process should be handled in the most economic and efficient manner, and certainly if it is possible to develop one universal container that will serve all purposes, then it would be desirable to do so. We don't think that we have enough information now to say that that is the exclusive way that we sill ultimately proceed.

Mr. VALENTINE. Does your industry, Mr. Smith, support the LWR extended burnup program?

Mr. SMITH. A number of utilities, Mr. Valentine, have been negotiating with vendors with respect to arrangements that would extend the life cycle of the fuel. We think that there can be certain economies to achieve there. The current state of the matter is that, like many other arrangements between the vendor and the utility, it is something that is being negotiated between them. My own personal view is that it is a commercial activity, and like other commercial activities, should be encourged. I have not personally seen any information that would lead me to the recommendation that the Department of Energy should become involved in that as a part of its civilian waste management program.

Mr. VALENTINE. How many nuclear generating plants does CP&L operate?

Mr. SMITH. We have three in operation and one under construction.

Mr. VALENTINE. Now, just a couple of other questions, Mr. Smith. You know, on this panel, as well as in other places in the U.S. Congress, we have people, men and women who, for one reason or another, throughout life have decided to be Republicans, and there are none of them here. As fairness to them, I want to pose to you now two questions which we have been asked to submit for the minority party.

First, would you characterize, Mr. Smith, a Nuclear Waste Policy Act as establishing a very difficult roadmap? It appears that this is in the context of the schedule. Your candid appraisal of that schedule would be appreciated.

Mr. SMITH. Well, Mr. Valentine, I understand the nature of the complexity and the Department of Energy was first required to develop guidelines in the spring of 1983. It was a difficult process because it involved accommodation of the interests of States which differed because they had different geologic formations. The schedule was not completed until the summer. The guidelines were not first submitted to NCR until November.

I can understand why it has taken longer to develop the guidelines for site selection, but my concern is that there does not seem to be a parallel action going forward with the substance of the program, just how will we handle the material, how will we go about development of the first drilling? We seem to have, as I see it, let our involvement with the process, detract from spending the time that should have been spent, I believe, in parallel, on going forward with the substance of what must be done.

I was very concerned, as many people were, when the announcement was made in December that the site selection date was being removed from March of 1986 until perhaps December 31, 1990. There was no change in the final date of 1998 announced at that time, but I think it would be obvious to anyone who has followed this, that if you slip the site selection date by 3¾ years, and as complex as this is, then it does pose a great danger to whether or not one would expect to have the permanent repository in place in 1998, and we have grave concern about that.

Mr. VALENTINE. Thank you. The second question that I have been asked to pose for my minority brothers and sisters is as follows: What amount of dialog has been established between your industry oversight group and the U.S. Department of Energy on implementation of the Nuclear Waste Policy Act? Second, how active has your oversight group been to date?

Mr. SMITH. There are two oversight groups. One is chaired by Dr. Draper on my right, formed by the atomic industrial forum which includes not only the utilities, but it also includes the manufacturers, the architect engineers, and the vendors. There is a second group, a larger group in number. of some 40 utilities, that for many years has had a utility nuclear waste act group in place. This includes both the public sector and the private sector in the utility business.

Both of these groups have been active. Both of them, as far as I am aware, have been received by the Department of Energy in a cooperative manner. We certainly have had access to sit down and discuss our concerns with the appropriate people in the Department of Energy, and we would hope and expect that this would go forward. We believe that there are individuals in the Department of Energy who share our concerns about going forward with this on an expeditious and efficient basis.

Mr. VALENTINE. All right. Thank you very much, sir.

I just have one final question that I would like to have your judgment, your opinion, briefly, on this question. You are, I know you to be an energetic and efficient chief executive officer of a public utility, and I know you also to be an interested and involved and concerned and caring and useful citizen. You understand the problem that we have from both points of view.

Do you believe that the public utility industry and the U.S. Congress are moving with appropriate dispatch to approach and correct and find a solution to this problem?

Mr. **Smith**. First of all, Mr. Valentine, the Congress has acted, and I think it was a difficult process. Congress has acted. I think the Congress today, in hearings such as this, is exercising its oversight and review jurisdiction over the implementation of this, and I would say that the answer with respect to Congress is "Yes," and I would hope that Congress would continue to be very much involved.

With respect to the utility industry, long before the Nuclear Waste Policy Act of 1982 was enacted, members of our industry, of course, who personally had devoted their business and professional careers to the use of this technology for the benefit of their companies and their customers and their various organizations, had been working very, very diligently to see that we did develop, on an expeditious basis, a method of safely and securely and economically handling the permanent waste material, whether it be in the form of spent fuel or whether it be in the form of high-level waste following reprocessing.

I think that we need to continue to do that, and I can assure you that the executives in the utility industry with whom I am associated have a sense of urgency about this. I do think that the whole process is one that will drift and slow down unless there is constant attention given to it.

Mr. **Valentine**. All right. Thank you very much.

Mr. **Smith**. Thank you, sir.

Mr. **Valentine**. Mr. Leo Duffy? Mr. Duffy, we are ready to hear from you at this time. Mr. Duffy is general manager, Waste Technology Services Division, Westinghouse Electric Corp. We, as with the other witnesses, will receive your prepared testimony and it will go into the record just as it is prepared, and we will be glad to hear a summarization or just however you want to proceed.

We are delighted to have you here, sir.

Mr. **Duffy**. Thank you, Mr. Chairman. I will read from the paper.

I think we have an area of common interest. My daughter is a senior at the University of North Carolina. On a three-time-a-week basis I hear about the NCAA champions coming up. That is an area we will probably be looking at together.

Mr. **Valentine**. Well, Mr. Duffy, your daughter has exercised extremely fine judgment, or her family has, if she is at the University of North Carolina at Chapel Hill. Sherwood can tell you that.

Mr. **Duffy**. I thought so also, and visiting Chapel Hill over the time period, I think we have confirmed that.

Mr. **Valentine**. Of course, now, let me tell you this. Duke University in the Second Congressional District is also a very fine institution.

Mr. DUFFY. That is right. And I would have to say that my boss has a daughter at Duke University, so we have covered all bases in that area, but, thank you, again, Mr. Chairman.

STATEMENT OF LEO P. DUFFY, GENERAL MANAGER, WESTINGHOUSE WASTE TECHNOLOGY SERVICES DIVISION

Mr. DUFFY. My name is Leo Duffy, general manager of the Waste Technology Services Division of Westinghouse Electric Corp.

In the mid-1970's, Westinghouse made a long-term commitment to become a national leader in resolving the nuclear waste problems that remain as barriers to the future use of nuclear power.

As an example of these barriers, I would like to address the Philadelphia Inquirer article, "Forevermore: Nuclear Waste in America." It raises many valid issues on past performance and raises many, many questions for the future. Unfortunately, we feel it was done in an irresponsible and inflammatory method using fear and doom form of journalism. I would like to quote a few examples.

It says, " Forty years of postponing a nuclear decision"; "Forty years of half-hearted solutions"; "No matter what you have been told, industry, science and the medical community have been wrong time after time"; "There are 11 billion curies of nuclear waste existing at the present time and 42 billion curies can kill everyone on earth."; and "the game of cancer roulette".

This is certainly an interesting approach if the object is to scare the general public into panic, but it is irresponsible if the object is to solve a problem.

Westinghouse, as with many other corporations, Bechtel, General Electric, Dravo, Du Pont, EBASCO, Fluor, Gibbs & Hill, has made a corporate commitment in cooperation with the Department of Energy to help control and resolve the nuclear waste management problems of the United States. This commitment is described in detail in the attached magazine article reprint entitled, "Addressing the Nuclear Waste Issue: Update on Westinghouse Commitment," the text of which I would like permission to include in the record.

Today there is also increasing national attention focused on the environmental impacts of hazardous and chemical wastes. As a result, Westinghouse is committed to provide efficent, high techology products and services covering the full spectrum of waste management.

We have integrated all our efforts in the activities of both nuclear and nonnuclear waste into my division, the waste technology division. Our purpose is to focus our engineering efforts to enhance technology and transfer from Government projects to commercial applications and to deliver high quality products and services. We celebrate our first anniversary this month.

Let me give you a brief overview of our activities.

We are developing and demonstrating technologies to process, package, store, and dispose of high-level nuclear wastes and spent fuel. We have committed key technical scientific personnel to manage utility low-level radioactive wastes, and we are developing an innovative, we think at least, an innovative incinerator technology to apply to nonnuclear waste disposal.

Today I will focus on positive accomplishments in the high-level nuclear waste management area. Our involvement, achieved in support of DOE programs, demonstrates not only the Westinghouse capability and commitment to closing the fuel cycle, but the ability of Westinghouse and other industrial contractors to work as teams in support of DOE programs.

I would like to say that is, in our opinion, fairly significant, because no single company in the United States has the capability in the technology area to handle all the disciplines required to solve the nuclear waste problem, so you have to work as a team to efficiently get these programs under control and beat the schedules and costs required.

I will begin with what I consider to be the Nation's most significant high-level waste project, the West Valley demonstration project. This former spent fuel reprocessing facility closed its doors in 1972, leaving behind highly radioactive hot cells, some 600,000 gallons of high-level liquid waste, and two low-level waste burial grounds.

In 1981, the Department of Energy Idaho Operations Office chose Westinghouse to manage what is this country's only commercial high-level waste solidification project, and the Nation's largest and most extensive decontamination and decommissioning activity. Under the direction of the Idaho operations project manager, Westinghouse, as the prime contractor, is working with Dames and Moore and EBASCO to decommission the West Valley facility.

West Valley is providing critically important technology and valuable human resource skills while at the same time providing a national prototype for effective public relations on controversial nuclear issues. The facility has had two open house visits for Buffalo area residents and conducted tours through the facility for over 2,000 people. In addition, an active speakers bureau program was established in 1982, and 24 of our employee speakers have made over 300 presentations to local groups.

The project is proceeding on schedule and below the original estimated cost for completion. The attached magazine article reprint, "The West Valley Demonstration Project * * * A Nuclear Success Story," outlines the accomplishments at West Valley, and with your permission, I would like to include its text in the record.

[The article mentioned above follows:]

The West Valley Demonstration Project... A Nuclear Success Story

SPOTLIGHT

The West Valley Demonstration Project... A Nuclear Success Story

By Philip G. Woods, Public Information Manager, West Valley Nuclear Services Company

The purpose of the West Valley Demonstration Project is, simply put, to prove that nuclear waste can be managed safely in the United States. Passed in 1980 by the United States Congress, the West Valley Demonstration Act requires the Department of Energy to solidify over 560,000 gallons of liquid high level nuclear waste currently stored in an underground steel tank at West Valley, the site of a former nuclear fuel reprocessing facility near Buffalo, New York. Before the solidification process can begin, however, the sealed cells of the main facility where reprocessing once occurred must be decontaminated. That is, radioactive materials will be removed from these cells so that the existing facility can be used to house equipment and systems needed for converting the highly radioactive liquid nuclear waste into a durable solid form.

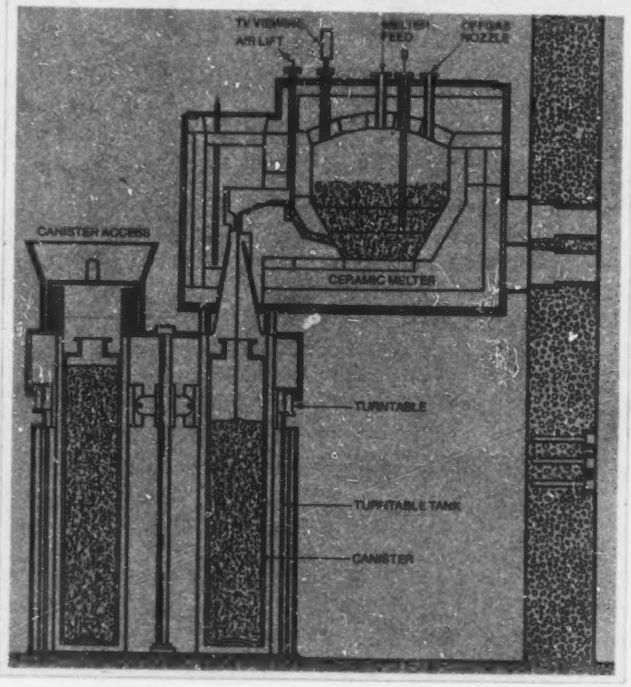
The West Valley Demonstration Project is operated for the Department of Energy by the West Valley Nuclear Services Company (WVNS), a subsidiary of Westinghouse Electric Corporation. WVNS engineers will demonstrate almost every aspect of nuclear waste management including the decontamination of a large nuclear facility and the safe handling, packaging and disposal of all kinds of low level and transuranic waste. Special decontamination approaches, techniques and tools are being developed to remove radioactive materials from the cells where reprocessing once took place. Equipment to remove solids which have settled to the bottom of the steel storage tank is under development. The conceptual design of the equipment to solidify liquid high level waste is almost complete. Project costs, including decontaminating the facility prior to installing the solidification equipment, are estimated at less than $500 million (constant FY 1983 dollars).

Spent nuclear fuel management, consolidation and transportation is also being done at the West Valley facility. (The spent fuel is from the plant's reprocessing era—watch for a complete story on this in an upcoming issue.) With the exception of mill tailing management and the development of a geological waste repository, West Valley engineers are involved with every facet of the safe and successful solution of nuclear waste problems.

Nuclear Waste to be Atomically Bound into Borosilicate Glass

In the United States, as well as in other countries throughout the world, glass has been selected as the preferred waste form for isolating liquid nuclear wastes. Borosilicate glass has been selected as the form into which the 560,000 gallons of liquid high level waste will be blended. It is a very strong, heat resistant, non-dissolvable glass similar to Pyrex.

A slurry fed, ceramic melter will mix liquid and solid high level waste (the slurry) with borosilicate glass ingredients in a ceramic-lined vessel. Electrodes inside the vessel will transfer 250 kilowatts of electrical energy into the melt, which is then poured into a stainless steel cylinder resembling a giant thermos bottle two feet in diameter and ten feet tall. The slurry fed, ceramic melter is designed to run con-



(Figure 1) Borosilicate glass ingredients are combined at 1150 degrees C. with high level nuclear waste in a slurry fed, ceramic melter. The mixture is poured into stainless steel canisters, where it hardens into a durable solid.

tinuously. When a canister is full of molten glass, it rotates toward a storage position as an empty canister moves under the melter, carried by a carousel-like piece of equipment, as shown in Figure 1.

A full scale, slurry fed ceramic melter solidification system is being designed for installation at West Valley. This system will include not only key components but will also demonstrate the process and equipment. The Component Test Stand, as this prototype system is called, will also verify that the system can be operated by remote control (necessary when using a radioactive feed) and it will provide operator training. The foundations will be seismically designed so that thick shield walls can be erected around the equipment, which can then be used to process radioactive waste. The prototype melter should be ready for installation at West Valley late in 1984.

A comprehensive 300 page Project Environmental Impact Statement finished in July, 1982 concluded that the liquid nuclear waste can be safely solidified and that negligible health risk will result from the Project. An independent study by Johns Hopkins University School of Public Health also concluded that no discernible radiation health effects would result from the planned waste solidification activities.

Ray C. Mairson, President of West Valley Nuclear Services Co., reports that the solidified borosilicate glass logs containing the wastes will be transported to a federal repository for permanent disposal. "When placed deep in the earth in a stable geological formation, the waste will be isolated from our environment and will eventually decay into a stable, non-radioactive solid," he explained. Mr. Mairson said that the actual solidification of the liquid waste is now scheduled to begin in 1988.

Integrity of Liquid Waste Storage Tank Confirmed

A considerable amount of attention has been focused on the carbon steel tank in which the liquid high level waste is stored. Built in 1964, this tank contains the fission products remaining after uranium and plutonium were extracted from dissolved nuclear fuel. Some 640 metric tons of nuclear fuel were reprocessed at West Valley from 1966-1972. The tank, which sits on perlite blocks in a steel saucer inside a concrete vault, has been inspected to insure its integrity. The wastes have been sampled, and a 1/6th scale model of the tank and its complicated internal grid structure has been constructed to help engineers determine how to best remove the solidified sludge present in the base.

To confirm the tank's integrity, engineers lowered inspection equipment into the space between the outside of the steel tank and the inside of the concrete vault. Remote arms were unfolded, providing a track for inspection equipment to travel around the circumference. In addition to a detailed photographic and video inspection, the tank was ultrasonically examined to assure there were no hidden flaws in the steel. Test results confirm that the tank's half-inch thick, plate steel walls are sound, providing safe interim storage for the radioactive liquid.

Internal Grid Structure Complicates High Level Waste Sludge Removal

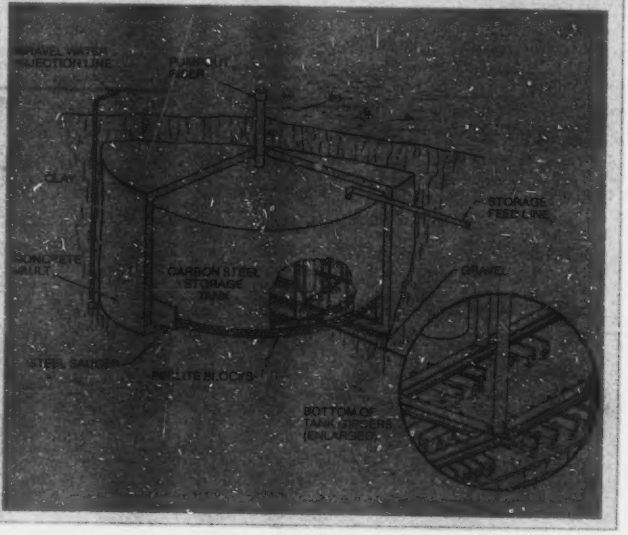
Figure 2 illustrates the steel tank and concrete vault arrangement and shows the complicated internal grid structure in the base of the tank. The nine inch I beams, the 12 inch girder plates and other structural members in the bases were designed to stiffen the tank against over-pressurization and to support the roof of the concrete vault which surrounds the tank. These obstructions, however, provide a special challenge because the solids in the high level waste have settled into a thick sludge surrounding this grid structure, leaving a clear yellowish liquid supernatant in the upper portion of the tank.

Since the 75 feet in diameter tank has only two openings in its top, an articulated arm is used to lower special probes into the sludge at positions other than directly below an opening. Special buoyancy probes and shear vanes were used to determine physical properties of the sludge. Measurements showed that the sludge has a stiff clay-like consistency and is about 18 inches deep (the internal grid structure rises about three and one half feet above the floor of the tank). An actual sludge core sample will be taken in the fall of 1983 and analyzed to more exactly determine the sludge's makeup. Engineers are using the 1/6th scale model of the tank to help design special sluicing pumps to stir up the sludge so it can be removed from the tank.

High Level Waste Samples Determine Melter Feed Chemistry

A number of high level waste samples have been taken of supernatant at various levels in the tank. The samples were drawn with an air jet eductor through one of two openings in the top of the tank.

Analysis of the waste samples shows that the radioactivity is about evenly divided between the supernatant and the sludge. The principal radioactive isotope in the supernatant is cesium 137 and the main constituent in the sludge is strontium 90. In fact, except for cesium and traces of dissolved strontium, the supernatant is essentially free of radioactive materials.


GRAVEL WATER INJECTION LINE
PUMPOUT RISER
CLAY
STORAGE FEED LINE
CONCRETE VAULT
CARBON STEEL STORAGE TANK
GRAVEL
STEEL SAUCER
PERLITE BLOCKS
BOTTOM OF TANK GIRDERS (ENLARGED)

(Figure 2) 560,000 gallons of high level waste are stored in a carbon steel tank, which sits inside a concrete vault. A thick sludge has settled into a complex internal grid structure which complicates removal of the waste from the tank.

Project engineers are therefore investigating methods to remove these radioactive elements, thereby decontaminating the liquid so that it can be treated as very low activity waste. Using actual samples of West Valley liquid waste, several methods of decontaminating the supernatant are being investigated, including organic and inorganic ion exchange and in-tank precipitation, to determine which works best.

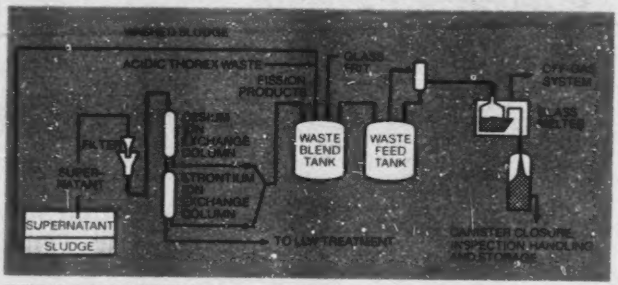
Figure 3 shows the makeup of radioactive materials which will be combined and fed to the ceramic melter for solidification into borosilicate glass. In addition to the cesium and strontium from the supernatant and the sludge, there is also 12,000 gallons of acidic thorex waste to be fed to the melter. This thorex waste, which is stored on-site in a small, separate stainless steel tank, resulted from a special demonstration reprocessing run of thorium rich fuel from the first Indian Point core. (The thorium was transmuted or bred into uranium 233, which is still stored, unused, at Oak Ridge).

Four full-scale borosilicate glass logs have been produced using a slurry-fed ceramic melter at the Department of Energy's Pacific Northwest Laboratory. These tests used a waste feed stream chemically like the West Valley waste composition (although non-radioactive). The test runs have provided valuable data to help project engineers finalize the composition of the borosilicate glass product and to confirm slurry-fed ceramic melter design principles.

West Valley Facility to be Decontaminated

When nuclear fuel was reprocessed at West Valley, all radioactive materials were handled in closed concrete rooms with concrete walls, which are typically three to five feet thick. Only a few of the largest rooms, called cells, have thick, oil filled, observation windows. These sealed cells now must be decontaminated so that solidification equipment and other supporting and storage systems can be installed. Table 1 lists the major cells at West Valley, their size, and levels of radiation and contamination.

(Figure 3) Radioactive materials removed from the liquid nuclear waste are blended with high level waste sludge and acidic thorex waste and then mixed with molten borosilicate glass in the slurry fed ceramic melter.



(Table 1): Sealed Cell Characterization Program

Cell	Dimensions (W,L,H)	Radiation* Levels (R/HR)	Smearable Contamination DPM/100 cm² Beta	Alpha
Chemical Process Cell (CPC)	22' × 93' × 43'	12.0 - 56.0	$>10^6$	$>10^6$
CPC Crane Room	22' × 28' × 16'	0.015 - 0.020	not determined	
Equipment Decon Room (EDR)	32' × 44' × 25'	0.030 - 0.200	10^4	10^2
General Purpose Cell (GPC)	11' × 46' × 20'	700.0 - 1800.0	not determined	
GPC Crane Room	10' × 12' × 20'	0.050 - 0.075	not determined	
Process Mechanical Cell (PMC)	52' × 12' × 25'	142.0 - 300.0	not determined	
PMC Crane Room	27' × 16' × 16'	0.300 - 3.000	not determined	
Scrap Removal Room (SRR)	40' × 12' × 14'	0.001 - 0.020	10^1	10^1
Extraction Cell 1 (XC-1)	16' × 16' × 55'	4.0 - 57.0	not determined	
Extraction Cell 2 (XC-2)	21' × 21' × 57'	0.003 - 0.044	$>10^6$	$>10^6$
Extraction Cell 3 (XC-3)	16' × 21' × 57'	0.001 - 0.012	$>10^6$	$>10^6$
Product Purification Cell (PPC)	16' × 20' × 57'	0.001 - 0.175	$>10^6$	$>10^6$
Liquid Waste Cell (LWC)	45' × 16' × 19'	0.050 - 3.000	$>10^5$	$>10^7$
Acid Recovery Cell (ARC)	29' × 31' × 32'	0.500 - 1.000	not determined	
Off-Gas Cell (OGC)	12' × 32' × 31'	1.0 - 3.0	not determined	
Uranium Product Cell (UPC)	46' × 27' × 13'	0.001 - 0.003	10^5	10^5
Fuel Receiving & Storage (FRS)	50' × 150' × 20'	0.001 - 0.300	10^1	10^1

*Whole Body Exposure

In planning cleanup methods, it is important to know the general condition of a cell and its approximate radiation and contamination levels. High radiation fields and high levels of contamination present different challenges. High fields typically emanate from inside a sealed piece of equipment, such as a nuclear fuel dissolver. High levels of contamination, on the other hand, are found where nuclear fuel was mechanically handled, such as where it was chopped up so that it could be more easily dissolved.

Obviously, a great deal of care and preplanning must be taken before even a remote entry is made into a cell with radiation fields potentially as high as 1800 REM per hour or levels of contamination approaching a million disintegrations per minute per 100 sq. cm.

Sealed Reprocessing Cells are Characterized Prior to Cleanup

Entry into the sealed reprocessing cells can be made either remotely or by manned entry, depending on dose rates. Remote entries are first performed to determine radiation and contamination levels in the cell. Those cells not equipped with remotely operable manipulators are entered by boring an eight inch hole through the ceiling of the cell and inserting closed circuit television cameras to determine the condition of the equipment in the cell and to identify potential problems such as leakage and accumulation of materials.

Airborne samples are taken, radiation detectors and thermoluminescent dosimeters (TLDs) are lowered into the cells to determine the radiation field, temperature measurements are made and grab samples of loose contamination are taken from accessible surfaces. These preliminary inspections provide the means to plan manned entries. Thus far, six cells have been surveyed remotely and manned entries have been made into five cells.

Manned Entries Yield Valuable Data

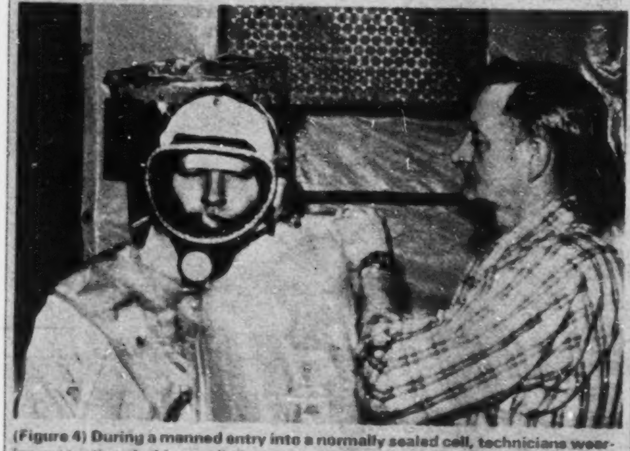
During manned entries, samples are taken from the floors for isotopic analysis, concrete samples are taken from the walls to determine the depth of contaminant penetration, various decontamination solutions are tested to determine their effectiveness, and photographs are taken for use in planning equipment removal and final decontamination methods. Protection of the workers and prevention of the spread of contamination outside the cell during manned entries are achieved by a combination of factors, planning and technique being the most important.

Each worker who enters the cell wears four layers of anti-contamination clothing, a forced-air respirator and a forced-air bubble hood (Figure 4). A radio headset with a voice-actuated microphone puts each worker in contact with the entry director. The director is also in visual contact with the workers through a closed circuit television system. The camera is operated by the first back-up man who is fully dressed and equipped for cell entry, but remains just outside the cell entryway.

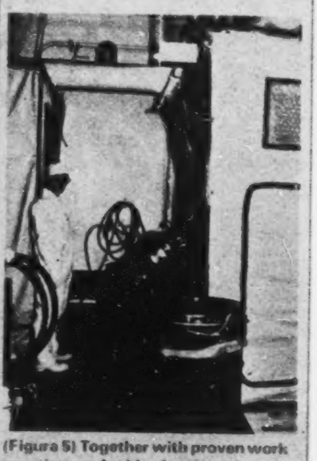
A double-chambered contamination control tent is erected and sealed around the entryway to the cell as shown in Figure 5. This tent, along with proven work practices, provides the major barrier to the spread of contamination. Filters in the tent permit air to flow through the tent chambers into the cell when the entryway to the cell is opened (a reduced atmospheric pressure is always maintained in the cell).

The use of these contamination control measures has proved very effective in controlling contamination spread. Thus far, in the over 100 entries which have been made, contamination has been contained within the tent chamber at the entryway. This has been accomplished by removing and bagging the first layer of anti-contamination clothing in the cell, the second and third layers in the two chambers of the containment tent, and the final layer in a controlled step-off area immediately outside the tent.

The use of strippable coating in the innermost chamber of the tent has proved very effective in decontaminating the tent. The walls are sprayed periodically and cleanup has become a simple and effective matter of peeling off the coating.



(Figure 4) During a manned entry into a normally sealed cell, technicians wearing protective clothing, radio headsets and voice actuated microphones are in constant contact with the entry director, who monitors progress with a closed circuit television system.



(Figure 5) Together with proven work practices, a double chambered contamination control tent erected around a cell entryway prevents the spread of radioactive materials during manned entries into sealed cells.

In the first 18 months of the project, over 15,000 sq. ft. of plant surface area, including 7,300 sq. ft. of floor have been decontaminated. Cleanup efforts shown in Figure 6 have changed the Master Slave Manipulator Repair Shop from an airborne area (with loose contamination levels as high as 10^5 dpm/100 cm^2 and radiation fields up to 100 mR/hr) to a clean area. The Chemical Crane Room, at the start of decontamination, had a general field of 40 to 50 mR/hr, with localized "hot" spots up to 10 R/hr.

Radiation Levels Require Remote Removal of Equipment

Because levels of radiation and contamination are so high, all the equipment in the Chemical Process Cell must be removed remotely. WVNS engineers are designing special tools to disconnect and remove the large stainless steel nuclear fuel dissolvers and the connecting maze of pipes. Only two remote crane control bridges are available in the cell to carry the equipment needed to remove everything.

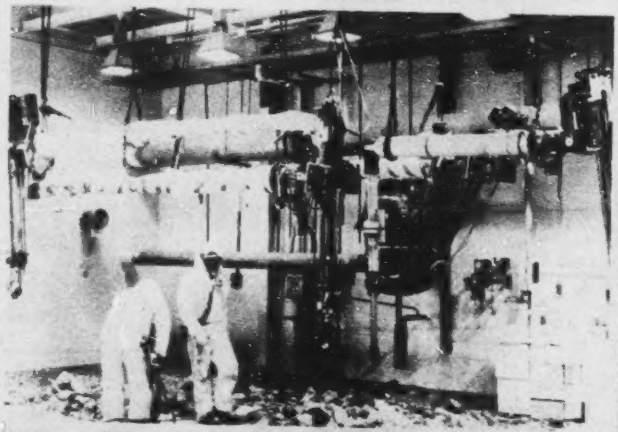
To help plan this work, WVNS engineers designed a survey instrumentation package which was carried into the cell by one of the two remotely operable cranes. The package included a high resolution television camera to survey the condition of the cell. It also carried equipment to determine radiation fields in the cell (which range as high as 200 R). The remote manipulator arm on the other crane bridge was used to take swipes to determine smearable contamination levels. Some of the swipes read as high as 400 mR per hour.

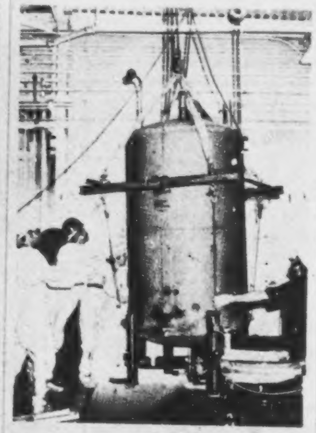
In areas where levels of contamination are high, innovative remote decontamination equipment will be needed.

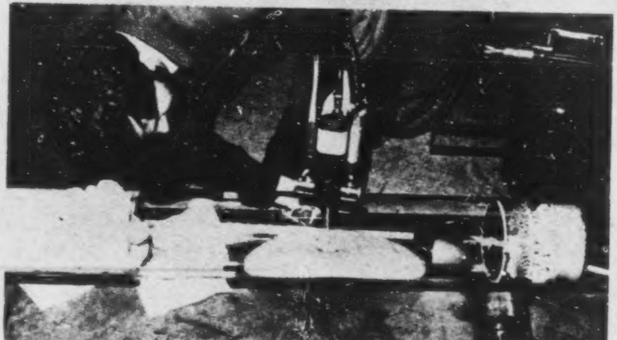
In cells where radiation levels are less intensive, more conventional decontamination techniques to cut pipe and remove concrete are used.

All decontamination work is extensively preplanned to determine what kinds of radioactive isotopes might be encountered and the appropriate level of protection for the worker.

Using these kinds of decommissioning techniques, over five miles of pipe and 26 stainless steel tanks have been removed from the Extraction Chemical Area of the plant. Part of the tank removal operation is shown in Figure 7. Innovative approaches are needed for something as simple as cutting and removing pipe. To prevent the possible spread of contamination, each pipe is filled with expandable foam before it is cut, as shown in Figure 8.







(Figure 6 upper left) Over 7300 square feet of floor have been decontaminated at the project including the manipulator repair area.

(Figure 7 upper right) In the Extraction Chemical Cell, 26 stainless tanks have been removed using standard decommissioning techniques.

(Figure 8 lower left) Before a pipe is cut, it is fitted with expandable foam to prevent the possible spread of contamination.

Environmental Enhancement a Top Priority

The safe and successful solidification of the waste stored at West Valley will clearly enhance the local environment. To reassure residents that the project in fact solves a problem rather than creates one, a great deal of effort is focused on environmental and public information programs.

To prove that the project does not add to radiation levels in the area, over 3300 acres surrounding the West Valley Demonstration Project site have been environmentally surveyed. This reference study included direct radiation measurements of over 11 million square feet of property. Water, air, soil and vegetation samples have been collected and analyzed.

In the future, these results will be used to conclusively show that project operations have not negatively altered the environment.

Public Information Important to Project Success

The public information program at West Valley is also being developed as a model for future nuclear waste management projects. Its basis is aggressive, open communication. When WVNS engineers assumed control of the facility in February, 1982, media reaction was one of suspicion and fear, despite the fact that the project provided a solution to an existing environmental problem. While the former site operator discouraged media coverage of on-site activities, the demonstration project has had from its inception, a full time, staff level public information management function and a policy of openness with the media.

The WVNS policy of providing the media with ready access to project management and with reasonable access to the site builds media trust in the management team. While negative charges are still sometimes reported, they are rarely aired until the reporter checks the facts with the public information office. Maintaining the trust of the local and regional media has been achieved through the prompt and accurate reporting of both accomplishments and problems, and by providing frequent opportunities for reporters to observe project operations first hand. Without a doubt, use of the media is an effective method of disseminating information about the project.

In addition, a key feature of the public information program is that, from the outset, it identified the various public audiences in the area and their information needs regarding the project. Local community educators, church members, town administrators and leaders from civic and business groups were identified and contacted. Tribal leaders from the nearby Seneca Indian Nation were also consulted.

The DOE project director, the WVNS project manager and the public information manager then met, early on, with each leader to explain the project's purpose, and to identify the public information manager as the party to contact for further information.

These community leader contacts have been continually reinforced by providing them with ongoing news and project status information. This has helped forge a link from the project to the community, via its opinion leaders.

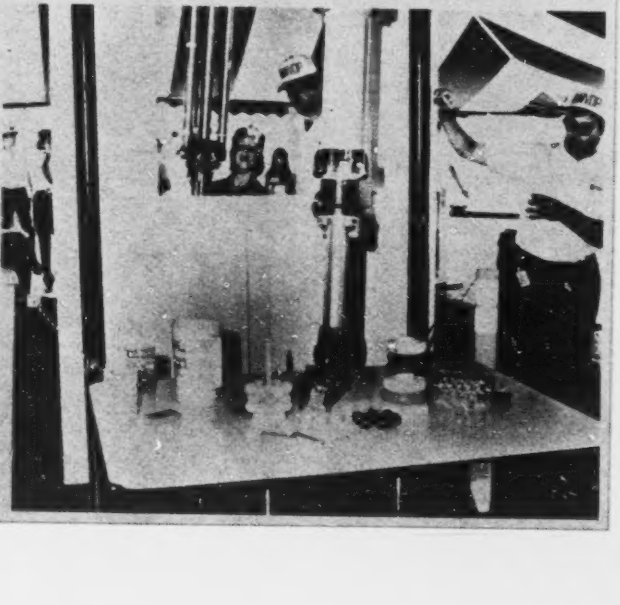
An active speakers bureau program was established in 1982, and 24 employe speakers have made over 200 presentations to local groups. The speakers bureau greatly multiplies the number of direct community contacts that can be made, thus enhancing public awareness about the project. Speakers bureau participation also enhances employe interest in the community, in the project and in public issues.

Speakers bureau participants meet weekly and discuss project accomplishments and methods to present them. Members research topics and make presentations to the group on issues which are likely to come up as questions. Practice, preparedness, message strategy, and peer critique are emphasized.

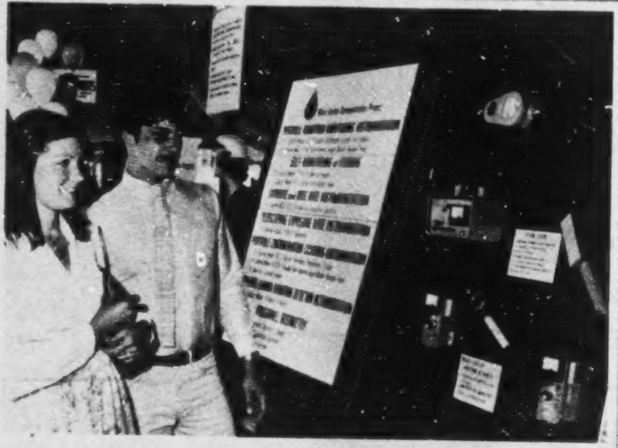
The public information program intends to meet the information needs of all groups in the community, including groups opposed to the project. In fact, establishing a channel of communication with project opponents is a necessity. The rationale behind project decisions is carefully explained to opposition groups, whose members are generally well informed about project issues. Special opportunities for opposition groups to discuss various issues with the facilities manager, the radiological health and safety manager, and the project director have been provided.

The largest, and one of the most successful, public information programs is an annual facility open house and tour. The open house is announced in the local and regional newspapers and by a fact sheet mailing. Two open house tours have been held, with this year's attracting over 800 people. Tours through the facility included stops at the inspection work in the Chemical Reprocessing Cell, an overview of the Waste Storage Tank Area, a look at supernatant analysis by remote control and the Spent Fuel Storage Pool where reactor fuel assemblies left over from reprocessing days are stored pending their removal by several utility companies.

A large display area at the open house included a functioning remote control manipulator (Figure 9) and numerous radiation instrumentation displays (Figure 10).



(Figure 9) A remote manipulator illustrated how radioactive materials can be safely handled in sealed cells to visitors at this year's public open house.

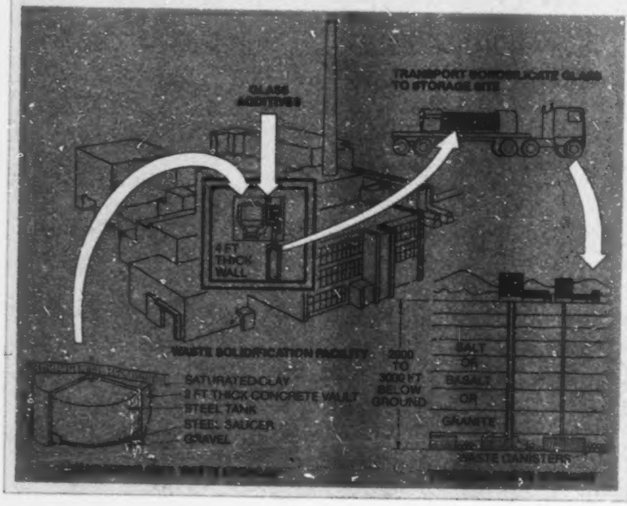


(Figure 10) Cuests at a project open house toured the facility and saw a number of displays, including this one on radiation instrumentation.

While at times the task of providing information to the public seems overwhelming, the need to make people aware of the role of the project in demonstrating the safe management of nuclear waste is clear.

West Valley Project to Demonstrate Safe Nuclear Waste Management
Some of the many facets of the West Valley Demonstration Project are illustrated in Figure 11, including the removal of the waste sludge from the high level waste storage tank, the immobilization of nuclear waste in borosilicate glass and finally, the transportation of the solid waste to a federal repository. Not shown, but equally important, are the demonstration of decontamination and decommissioning techniques on a large scale as well as the safe handling, packaging and disposal techniques for all kinds of low level and transuranic wastes.

The safe, successful, and timely completion of the West Valley Demonstration Project will establish that the United States has the capability to manage all kinds of nuclear waste.■


GLASS ADDITIVES
TRANSPORT BOROSILICATE GLASS TO STORAGE SITE
4 FT THICK WALL
WASTE SOLIDIFICATION FACILITY
SATURATED CLAY
2 FT THICK CONCRETE VAULT
STEEL TANK
STEEL SAUCER
GRAVEL
2000 TO 3000 FT BELOW GROUND
SALT OR BASALT OR GRANITE
WASTE CANISTERS

(Figure 11) The West Valley Demonstration Project will prove that high level liquid nuclear waste can be safely managed by converting it into durable borosilicate glass, which can then be transported to a federal repository for disposal deep in the earth.

West Valley Nuclear Services Company, Inc.
P.O. Box 191
West Valley, NY 14171

A subsidiary of Westinghouse Electric Corporation

Mr. Duffy. For all that, West Valley is just one of six major projects we have underway in the high-level radioactive waste, spent fuel and decontamination and decommissioning areas.

Under the direction of the Albuquerque operations project manager, Westinghouse, in conjunction with Bechtel, Dravo, and the U.S. Army Corps of Engineers is developing the experience base for permanent disposal technology. Since 1977, we have been techninal support contractor for the Government's Waste Isolation Pilot Plant at its project near Carlsbad, N. Mex.

WIPP is a permanent geologic repository for defense generated transuranic waste and it will also demonstrate high-level waste disposal in salt. Late in 1983, the Department of Energy initiated full WIPP construction. To date, two shafts have been drilled, one a 12-foot diameter and the other a 6-foot diameter, to a depth of 2,150 feet.

In addition, nearly 2 miles of underground drifts or tunnels have been excavated as an integral part of the WIPP facility which is scheduled to be completed in 1988. Although WIPP was intended to receive only defense generated waste, its design, construction, operation, and economics will be very similar to what nuclear utilities are currently paying for developing, a permanent Federal repository for commercial nuclear waste.

The project hosts on the average 100 visitors per month. The DOE is working directly with the New Mexico Environmental Engineering Group, a DOE sponsored technical advisory committee to the State of New Mexico.

We are also deeply involved in what is perhaps the most critical program in the nuclear industry today, the ongoing recovery operations associated with the defueling at Three Mile Island. This past June we signed a contract with GPU Nuclear to supply special services, equipment, tooling, training, and qualified personnel to accomplish the defueling on TMI-2. This task is considered to be the most sensitive, visible, and demanding in the overall unit 2 recovery plan. Success on this job is essential if nuclear power is to return to its role as an element in future electrical generation.

Working with Bechtel and EG&G, Idaho, we have evaluated conventional technologies for the removal of the core and debris. In addition, we have submitted to GPU and Bechtel a candidate design for a system which will remove debris using a remote operating robot arm which will feed a shredder and vacuum system. This system is currently under design review by the technical advisory group for GPU and Bechtel, and we are convinced that the system can offer accelerated removal schedule with significant reduction in exposure. The concept is based on state-of-the-art robotics that we have developed at Westinghouse and shredder technologies currently used in Department of Energy programs. At the moment, we are well into the process of engineering this effort.

As you are well aware, the policy decision made by President Carter in 1977 to indefinitely defer reprocessing of spent fuel from commercial reactors has a major impact on U.S. nuclear fuel cycle and waste programs. Emphasis is now focused solely on long-term management of spent fuel.

The Nuclear Waste Policy Act of 1982 identified the Federal Government's responsibility for accepting commercially generated spent fuel and high-level waste for storage and eventual disposal in deep geologic repositories. The Government also committed itself to a contingency plan for a monitored retrievable storage facility to store excess utility spent fuel safely until a permanent repository is available.

Westinghouse, along with Parsons & Golder Associates, has been chosen to develop six conceptual designs for the monitored retrievable storage facility. There are three basic criteria which the design must meet.

First, they must allow continuous monitoring, management, and maintenance for the foreseeable future. Second, they must make retrieval easy, and third, they must be engineered to last as long as possible, 50 to 100 years.

Until an MRS facility is available, utilities must provide for their own storage of spent fuel unless they can meet the conditions specified for interim Federal away from reactor storage. Because many plants have limited at-reactor spent fuel storage pool capability, reracking existing pools to incorporate high-density storage racks and spent fuel consolidation will be necessary.

Beyond these temporary fixes, it may be necessary to use other means, and I believe that dry storage at reactor sites, with its modular characteristics and phased investment pattern will be important for the nuclear industry.

One of the major advantages of dry storage is the flexibility presented by the various dry storage systems. Through our work as the technical support contractor for DOE Nevada operations, we have designed, developed, and demonstrated three promising at-reactor dry storage technologies, dry wells, concrete casks or silos, and air cooled vaults. We have, at the same time, assessed their economics and licensability.

My point in delineating the present progress of these programs is to address measurable successes on major DOE projects. Through technology transfer, these programs are contributing to the control and the solution of nuclear waste problems in the United States and throughout the world.

Contrary to the theme of the Philadelphia Inquirer, the American scientific community, working in partnership with the Government, is working with the Department of Energy to solve a major potential threat to the human environment.

I think handwringing and fearmongers do not solve problems. In 200 years, the American ingenuity has made more progress for mankind than any nation or people in the past 5,000 years.

The Low-Level Waste Policy Act of 1980 and the recently passed Nuclear Waste Policy Act are not the panaceas or total solutions to the waste problems. They are just a start. There are still many tough problems to solve.

To paraphrase Dr. Robert Schuller's book, tough problems never last, but tough people do. American industry is made up of tough people, scientists, engineers, and technologists, and we will solve the tough problems.

I believe if the nuclear waste program maintains its present priority that it has received over the past 4 years, the team of the Government and industry, through hard work and open public information programs, can solve the problems.

It is about time we Americans got off the doom and gloom train and started back on the course of the power of positive thinking. We, as a nation, have accomplished the impossible over 200 years, and we should get off the theme of the handwringing of the past and get on with the future, a future in which there is no nuclear nightmare, as described by Dr. Lynn E. Weaver, dean of engineering at Auburn University. I would like to submit his article also as a piece for the record.

[The article mentioned above follows:]

ATLANTA JOURNAL-CONSTITUTION December 11, 1983

NO NUCLEAR NIGHTMARE

Engineers, scientists say waste problems are handled safely

By Dr. Lynn E. Weaver
Special to The Journal-Constitution

For the engineers and scientists involved both directly and indirectly in commercial nuclear energy, the topic of managing nuclear waste is of particular concern. Not because of its technical difficulties, where they exist, but because of the widespread misunderstanding and mythology that have evolved around the subject.

Indeed, for many, it is particularly frustrating to find so little public recognition of the vast knowledge that has accumulated over the years as well as recognition of the remarkable degree of scientific consensus on the issue. The misrepresentations common in this debate go beyond the narrow subject of nuclear energy, often representing a fundamental misperception of the practice of modern science and engineering.

What does it mean when you are told that there is enough radioactivity in the nation's nuclear waste to kill everybody in the United States? Nothing. At least, this statement is no more informative or relevant than observing that one could kill 100 times more people with ammonia, a thousand times more people with phosgene gas and a million times more people with the chlorine used each year in the United States.

Is it true that science has not found a way to manage nuclear waste safely? No. There are many methods, but there is no large-scale waste disposal site in the country, primarily because the waste, as it is currently constituted

---

Last Sunday, The Journal-Constitution published in this space an article on the dangers of nuclear waste. The article was condensed from a series researched for 18 months and written by reporters Donald L. Bartlett and James B. Steele of the Philadelphia Inquirer.

In today's article, written exclusively for The Journal-Constitution, Dr. Lynn E. Weaver, dean of engineering at Auburn University, presents another view on the nuclear waste issue.

Dr. Weaver served as director of the School of Nuclear Engineering and Health Physics at Georgia Tech for 10 years. He also is a consultant to industry and government agencies on matters dealing with nuclear energy.

ATLANTA JOURNAL-CONSTITUTION December 11, 1983

No Nuclear Nightmare (continued--2)

Is it true that nuclear waste is the most toxic material ever produced? No. Many chemicals are comparably toxic, and virtually all of them are far more accessible.

Is it true that scientists and engineers have just started to realize that something must be done with the nation's nuclear waste? No. A large body of knowledge, extensive experiments, numerous studies, dozens of prototype operations and unprecedented international cooperation in the technical community have led to a wealth of information and expertise.

Should people be concerned about the proper disposal of nuclear waste? Yes. But the concern should be based on information and a balanced perspective.

There may be no other aspect of commercial nuclear energy, perhaps of modern technology, that is more misunderstood than that of nuclear waste. The most common refrain heard by those involved in the nuclear enterprise is "what are you going to do about the waste?" A fair question. A variety of facts, largely ignored in most popular discussions, needs to be presented in order to provide a useful answer.

From the perspective of the technical community, it was not surprising to find that the Congressional Office of Technology Assessment concluded in its 1982 study that there are "no insurmountable technical obstacles" to developing nuclear waste repositories, and cautioned that "the greatest single obstacle" is public confidence. Similarly, the National Academy of Sciences, in completing its far-ranging study on the nation's energy future, observed that there are "adequate technical solutions to radioactive waste disposal" but that "misunderstanding by the public" is a major problem.

Waste types very different

In short, nuclear engineers and scientists are as confident of the statement that a safe disposal site can be built in the near future as were aeronautical engineers a number of years ago with respect to the statement that the space shuttle would fly. Yet not only do many people lack this confidence, but they are also unaware that the scientific consensus is so extensive.

But what exactly is nuclear waste? The two principal types of nuclear waste — low-level and high-level — are so vastly different that the technical definitions do not describe the characteristics adequately.

Unfortunately, the two types of waste are often confused. In terms of volume, most of the nation's nuclear waste is low level. Low-level nuclear wastes typically comprise materials such as tools, gloves, paper, coveralls, filters and miscellaneous hardware contaminated with small amounts of radioactivity. About 40 percent of the volume of all this waste comes from medical, biological, and research activities, while the other 60 percent comes from the nuclear fuel cycle.

The amount of radioactivity in low-level waste is about 100 billion times lower than that contained in high-level waste. Low-level wastes can be typically less hazardous than common coal ash — which also happens to contain low levels of radioactivity.

Such comparisons are not intended to trivialize the importance of safe management of the wastes but rather to indicate the low potential for public risk even when errors are made.

Potential for harm . . .

The potential for harm with high-level nuclear waste is far greater. It is for this reason that so much attention and engineering have been devoted to its safe handling. High-level nuclear waste is usually considered to be the liquid and sludge materials left over from government operations, and the *solid* used fuel discharged from the nation's commercial nuclear electric generating stations. In terms of volume, government operations account for 90 percent of the waste.

In terms of the amount of radioactivity contained in the waste, there is

ATLANTA JOURNAL-CONSTITUTION December 11, 1985

No Nuclear Nightmare (continued -5)

Other scientifically verified methods exist. For example, the National Research Council of the National Academy of Sciences has examined a burial method proposed in Sweden which does not use glassification. The council concluded that the technique could isolate the radioactive materials for "hundreds of thousands of years" even if significant errors were made by the geologists. This assurance is based upon years of observations and experimentation. The speed at which the various radioactive elements can move in groundwater can be measured. The ground filters radioactive chemicals and slows their travel in much the same way that a charcoal filter removes chemicals from tap water.

It is known, for example, that virtually all of the radioactive elements move far slower than the groundwater — often hundreds and tens of thousands of times slower. Considering that the groundwater already takes several thousands to millions of years to reach the biosphere from deep underground, it is not surprising that very little radioactivity can reach the surface even under the worst circumstances.

However, because the lifetimes of some of the radioactive materials is so long — thousands and even millions of years — some claim that experiments can't be devised that would demonstrate adequately the behavior of nuclear waste. Fortunately, nature performed a number of experiments for us. One took place about two billion years ago.

Natural reactors in Africa

A group of natural, spontaneous nuclear reactors occurred in a uranium ore body in West Africa (something that cannot occur today because radioactive decay has reduced the concentration of the nuclear fuel in natural uranium). The reactors ran on and off for a few hundred thousand years and produced more than 12 tons of nuclear waste. By studying the location and quantities of the waste today, scientists are able to confirm modern experimental results. In fact, a recent National Academy of Sciences study concluded that a variety of studies of such natural phenomena shows that the rate at which the radioactive materials actually move in nature is "very much slower than laboratory measurements" indicate.

Thus, it is possible to say with a high degree of confidence that the solid nuclear waste materials, once placed deep underground in geologically stable areas, will present little if any risk for millenia. Should groundwater eventually enter a repository, the contaminated water, once it reached the surface, would present less risk to mankind than the risk we constantly face from natural radioactivity.

For the truly imaginative, it is possible to postulate some highly improbable scenarios for getting the nuclear waste from the repository into the biosphere; one example is a volcanic eruption (even though geologists would not select a site where one had occurred for millions of years). If such an eruption released one square kilometer of an underground repository into the air only two thousand years after burial, the effects of the natural radioactivity in the volcanic dust would be more serious than the effects of the nuclear waste.

An additional irony . . .

There is an additional irony regarding nuclear waste. Because it is radioactive, and because radioactivity is so easy to detect (single atoms can be found with relatively inexpensive instruments), the task of monitoring the integrity of a storage

SPENT FUEL ROD: High-level nuclear waste from commercial power stations is in the form of bundles of metal tubes that are filled with a solid ceramic-like material.

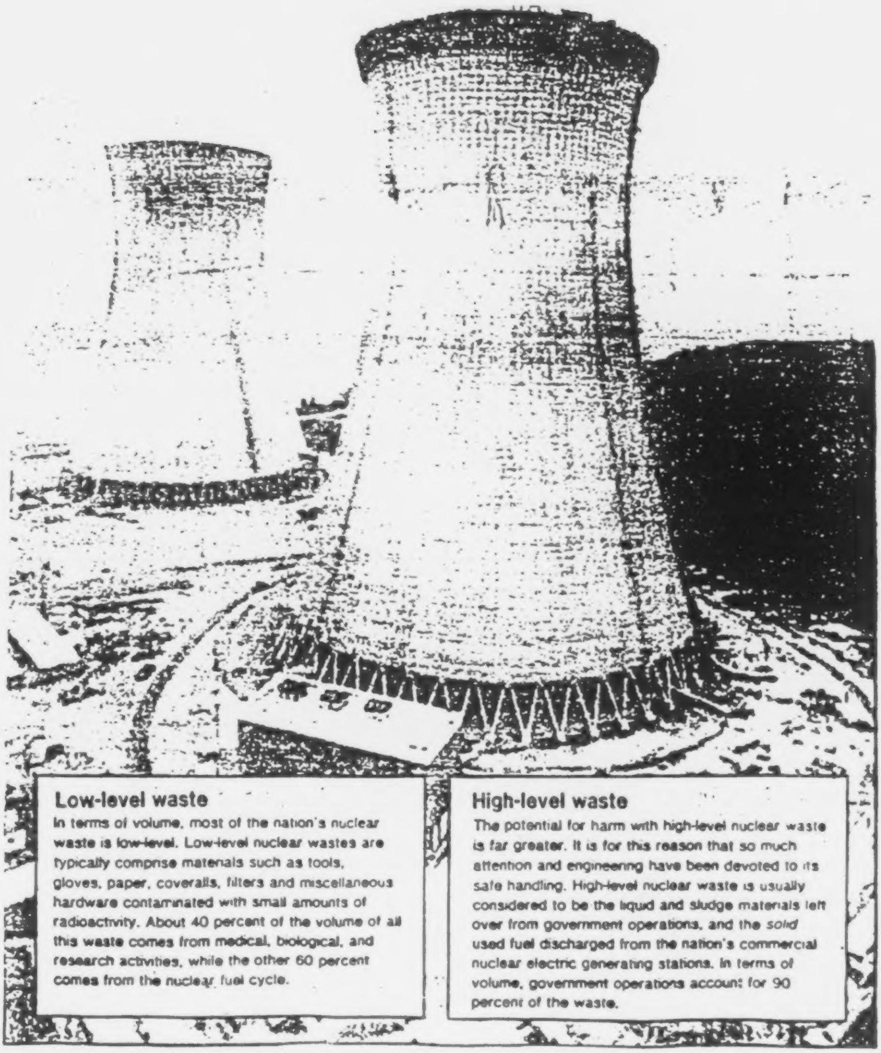
or disposal site and associated water supplies is remarkably easy. In addition, because naturally occurring radioactive elements similar or identical to those associated with nuclear waste are pervasive in the environment, it is possible to establish standards based on natural levels.

The National Academy of Sciences study had proposed that one criterion for a nuclear waste repository be that no individual could ever receive a radiation dose greater than 10 percent of what they receive each year from natural sources. They conclude that this is an achievable goal with current technology.

The next step is for government to act. It must begin by identifying a location for a waste repository according to the timetable set out in the Nuclear Waste Policy Act of 1982. After extensive technical evaluations, the president is to recommend a candidate site for the first repository by March 31, 1990. From a technical standpoint, there does not appear to be any reason that this goal cannot be met. It would be tragic if this nation defaulted on its ability to utilize effectively this source of electrical energy because of our inability to arrive at sound public policy based on sound science and engineering.

ATLANTA JOURNAL-CONSTITUTION December 11, 1985

No Nuclear Nightmare (continued--4)



Low-level waste

In terms of volume, most of the nation's nuclear waste is low-level. Low-level nuclear wastes are typically comprise materials such as tools, gloves, paper, coveralls, filters and miscellaneous hardware contaminated with small amounts of radioactivity. About 40 percent of the volume of all this waste comes from medical, biological, and research activities, while the other 60 percent comes from the nuclear fuel cycle.

High-level waste

The potential for harm with high-level nuclear waste is far greater. It is for this reason that so much attention and engineering have been devoted to its safe handling. High-level nuclear waste is usually considered to be the liquid and sludge materials left over from government operations, and the *solid* used fuel discharged from the nation's commercial nuclear electric generating stations. In terms of volume, government operations account for 90 percent of the waste.

Mr. DUFFY. I will be happy to answer any of your questions, and I thank you for the opportunity.

[The prepared statement of Mr. Duffy follows:]

STATEMENT OF LEO P. DUFFY, GENERAL MANAGER
WESTINGHOUSE WASTE TECHNOLOGY SERVICES DIVISION
TO THE
COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
U.S. HOUSE OF REPRESENTATIVES

Madam Chairman:

My name is Leo Duffy. I am General Manager of the Waste Technology Services Division of Westinghouse Electric Corporation.

In the mid-1970s, Westinghouse made a long-term commitment to become a national leader in resolving the nuclear waste problems that remain as barriers to the future use of nuclear power.

As an example of these barriers, the Philadelphia Inquirer recently ran a series entitled "Forevermore: Nuclear Waste In America." It raises many valid issues on past performance and raises many many questions for the future. Unfortunately, this is done with an irresponsible, inflammatory, fear and doom form of journalism.

Let me quote just a few examples:

"40 years of postponing a nuclear decision"

"40 years of half-hearted solutions"

"No matter what you have been told, industry, science and the medical community have been wrong time after time"

"There are 11 billion curies of nuclear waste existing at the present time; 42 billion curies can kill everyone on earth."

"The game of cancer roulette"

This is certainly an interesting approach if the object is to scare the general public into panic; but it is irresponsible if the object is to solve a problem.

Westinghouse, as with many other corporations -- Bechtel, General Electric, Dravo, DuPont, EBASCO, Fluor, Gibbs and Hill -- has made a corporate commitment in cooperation with the Department of Energy to help control and resolve the nuclear waste management problems of the United States. This commitment is described in detail in the attached magazine article reprint entitled "Addressing the Nuclear Waste Issue: Update On A Westinghouse Commitment," the text of which I would like permission to include in the record.

Today there is also increasing national attention focused on the environmental impacts of hazardous chemical and high-volume solid wastes. As a result, the Westinghouse commitment is to provide efficient, high technology products and services covering the full spectrum of waste management needs.

We have integrated this wide range of activities - both nuclear and non-nuclear -- into a single Division -- the Waste Technology Services Division. Our purpose is to focus our engineering efforts, to enhance technology transfer from government projects to commercial applications, and to deliver higher quality products and services. We will celebrate our first anniversary next month.

Let me give you a brief overview of our activities ...

We are developing and demonstrating technologies to process, package, store and dispose of high-level nuclear wastes and spent fuel.

We have committed key technical scientific personnel to manage utility low-level radioactive wastes.

And we are developing an innovative incinerator technology to apply to non-nuclear waste disposal. This technology will enable us to burn municipal solid and other non-toxic wastes more efficiently and produce usable process steam.

Today I will focus on positive accomplishments in the high-level nuclear waste management area. Our involvement, achieved in support of DOE programs, demonstrates not only the Westinghouse capability and commitment to closing the nuclear fuel cycle, but the ability of Westinghouse and other industrial contractors to work as teams in support of DOE programs. *([illegible])

I will begin with what I consider to be this Nation's most significant high-level waste project -- the West Valley Demonstration Project. This former spent fuel reprocessing facility closed its doors in 1972 leaving behind highly radioactive hot cells, some 600,000 gallons of liquid high-level waste, and two low-level waste burial grounds.

In 1981, the Department of Energy Idaho Operations Office chose Westinghouse to manage what is this country's only commercial high-level waste solidification project, and the Nation's largest and most extensive D&D activity. Under the direction of the Idaho Operations Project Manager, Westinghouse as the prime contractor is working with Dames and Moore and EBASCO to decommission the West Valley facility.

West Valley is providing critically important technology and valuable human resource skills, while at the same time providing a national prototype for effective public relations on controversial nuclear issues. The facility has held two open house visits for Buffalo area residents and conducted tours through the facility for over 2000 people. In addition, an active speakers bureau program was established in 1982 and 24 employe speakers have made over 300 presentations to local groups.

The project is proceeding on schedule and below the original estimated cost for completion. The attached magazine article reprint, "The West Valley Demonstration Project ... A Nuclear Success Story," outlines the accomplishments at West Valley. With your permission, I'd like to include its text in the record.

For all that, West Valley is just one of six major projects we have underway in the high-level radioactive waste, spent fuel and D&D areas.

Under the direction of the Albuquerque Operations Project Manager, Westinghouse, in conjunction with Bechtel, Dravo and the United States Army Corps of Engineers, is developing the experience base for permanent disposal technology. Since 1977, we have been Technical Support Contractor for the government's Waste Isolation Pilot Plant (WIPP) project near Carlsbad, New Mexico.

WIPP is a permanent geologic repository for defense-generated transuranic wastes that will also demonstrate high-level waste disposal in salt. Late in 1983, the Department of Energy initiated full WIPP construction. To date, two shafts have been drilled -- one a 12-foot diameter and the other a 6-foot diameter -- to a depth of about 2150 feet.

In addition, nearly two miles of underground drifts (tunnels) have been excavated as an integral part of the ~~full~~ WIPP facility, which is scheduled to be completed in 1988. Although WIPP is intended to receive only defense generated waste, its design, construction, operation and economics will be very similar to what nuclear utilities are currently paying for developing -- a permanent federal repository for commercial nuclear wastes.

The project hosts on the average of 100 visitors per month. The DOE is working directly with the New Mexico Environmental Engineering Group, a DOE-supported technical advisory committee to the state of New Mexico.

We are also deeply involved in what is perhaps the most critical program in the nuclear industry today -- the ongoing recovery operations associated with the defueling of the damaged reactor at Three Mile Island Unit 2. This past June, we signed a contract with GPU Nuclear to supply special services, equipment and tooling, training and qualified personnel to accomplish the defueling. This task is considered to be the most sensitive, visible and demanding in the overall Unit 2 recovery plan. Success on this job is essential if nuclear power is to return to its role as a key element in future electrical generation.

Working with Bechtel and EG&G Idaho, we have evaluated conventional technologies for removal of the core and debris. In addition, we have submitted to GPU and Bechtel a candidate design for a system which will remove debris using a remote operating robot arm which will feed a shredder and vacuum system. This system is currently under design review by the technical advisory group and Bechtel. We are convinced that this system can offer an accelerated removal schedule with significant reduction in exposure. The concept is based on state-of-the-art robotics developed by Westinghouse and shredder technologies currently used in DOE programs. At the moment, we are well into the process of engineering this effort.

As you are well aware, the policy decision made by President Carter in 1977 to indefinitely defer the reprocessing of spent fuel from commercial reactors has ~~had~~ a major impact on the U.S. nuclear fuel cycle and waste programs. Emphasis is now focused solely on the long term management of spent fuel.

The Nuclear Waste Policy Act of 1982 identified the Federal government's responsibilities for accepting commercially generated spent fuel and high-level waste for storage and eventual disposal in deep geologic repositories. The government also committed itself to a contingency plan for a Monitored Retrievable Storage Facility to store excess utility spent fuel safely until a permanent repository is available.

Westinghouse, along with Parsons and Golder Associates, has been chosen to develop six conceptual designs for such a Monitored Retrievable Storage Facility. There are three basic criteria which the designs must meet:

First, they must allow for continuous monitoring, management and maintenance for the foreseeable future.

Second, they must make retrieval easy ... either for future reprocessing of the spent fuel or permanent disposal in federal geological repositories.

And, third, they must be engineered to last as long as necessary --- possibly 50 to 100 years.

Until an MRS facility is available, utilities must provide for their own storage of spent fuel unless they can meet the conditions specified for interim federal away-from-reactor storage. Because many plants have limited at-reactor spent fuel storage pool capability, reracking existing pools to incorporate high-density storage racks and spent fuel consolidation will be necessary.

Beyond these temporary fixes, it may be necessary to use other means. I believe that dry storage at reactor sites, with its modular characteristics and phased investment pattern will become important.

One of the major advantages of dry storage is the flexibility presented by the various dry storage systems. Through our work as Technical Support Contractor for the DOE Nevada Operations, we have now designed, developed and demonstrated three promising at-reactor dry storage technologies -- dry wells, concrete casks or silos, and air-cooled vaults. We have at the same time assessed their economics and licensability.

My point in delineating the present progress of these programs is to address the measurable successes on major DOE projects. Through technology transfer, these programs are contributing to the control and solution of the nuclear waste problems in the U.S. and throughout the world.

Contrary to the theme of the Inquirer article, the American scientific community is working in a new partnership with the government to solve a major potential threat to the human environment.

Handwringing and fear-mongers do not solve problems. In 200 years, American ingenuity has made more progress for mankind than any nation or people in the past 5000 years.

The Low Level Waste Policy Act of 1980 and the recently passed Nuclear Waste Policy Act are certainly not the panaceas or total solutions to the waste problems. They are just a start. There are still many tough problems to solve.

To paraphrase Dr. Robert Schuller's book, "Tough problems never last, but tough people do." American industry is made up of tough people -- scientists, engineers and technicians -- who will solve tough problems.

I believe if the nuclear waste program maintains the priority it has received over the past four years, the team of government and industry, through hard work and open public information policy, can solve these problems.

It's about time we Americans get off the doom and gloom train and started back on the course of the power of positive thinking. We as a Nation have accomplished the impossible in just over 200 years. We should get off the theme of the Philadelphia Inquirer article and the hand-wringing of the past and get on with the future -- a future in which there is "no nuclear nightmare", as described by Dr. Lynn E. Weaver, Dean of Engineering at Auburn University in his article published in the Dec. 11, 1983 Atlanta Journal/Constitution -- "No Nuclear Nightmare -- Engineers, Scientists Say Waste Problems Are Handled Safely" (text attached for the record).

I shall be happy to answer your questions.

Mr. VALENTINE. Mr. Duffy, thank you very much. We will, of course, there is no objection to the receipt in the record of these supplemental documents that you mentioned. If you have them here or you may submit them within a reasonable time.

Mr. DUFFY. We have them, right.

Mr. VALENTINE. Has Westinghouse identified any decontamination work being undertaken at West Valley that is not unquestionably required for the solidification effort?

Mr. DUFFY. No, sir. The guidelines for the West Valley operation have been strictly identified as using existing facility to the maximum extent, and that is what we are doing.

Mr. VALENTINE. The Department of Energy has announced, Mr. Duffy, its intention to study the development of the universal spent fuel container, that is, one for storage and transportation and disposal. Does Westinghouse believe that such a container is a viable option, and does it support such development work?

Mr. DUFFY. It supports the development. As a matter of fact, as part of our program over the last 5 years, we have been looking at the economics of that operation. One of the things that has to be looked at is whether or not we are going to a repository, a monitored retrievable storage, or on-site storage, but the universal container looks to us as the potential for an economic saving.

Mr. VALENTINE. How much does Westinghouse believe is necessary to fully fund the LWR extended burnup program to accomplish its stated goal?

Mr. DUFFY. That is not in my division, but we are, as Mr. Smith identified, in a commercial environment, and to maintain our commercial leadership in a nuclear industry, we do have about a $10 million a year program to look at the extension of the light water reactor fuel cycle.

Mr. VALENTINE. Finally, let me ask you if you are aware that Exxon Nuclear plans a commercial demonstration of significantly higher burnup fuel early next year. Does Westinghouse have a similar plan?

Mr. DUFFY. Yes, we have plans with both our domestic customers and our international customers and our international licensees to demonstrate this type of fuel in other reactors.

Mr. VALENTINE. Thank you very much for sharing this valuable information with the subcommittee, Mr. Duffy.

Mr. DUFFY. Thank you, Mr. Chairman.

Mr. VALENTINE. Our next witness is Mr. Warren P. Chernock. He is vice president for development, nuclear power systems, C-E power systems, Combustion Engineering, Inc.

Mr. CHERNOCK. Mr. Chairman, you came close. It is Mr. Chernock.

Mr. VALENTINE. Well, that is what they say, that close only counts in horseshoes and handgrenades.

Mr. CHERNOCK. Right.

STATEMENT OF WARREN P. CHERNOCK, VICE PRESIDENT, DEVELOPMENT, NUCLEAR POWER SYSTEMS, C-E POWER SYSTEMS, COMBUSTION ENGINEERING, INC.

Mr. CHERNOCK. Mr. Chairman and members of the subcommittee, I am here today to discuss the extended burnup program. I have prepared written testimony, and I request that it be made part of the record. I intend to, in my oral presentation, highlight some of the items in the written testimony and expand on some of the reasons for supporting the program.

I would like to compliment this subcommittee for its past support of the extended burnup program, especially under circumstances in which budgetary atmospheres have been rather severe.

I think it is timely that my presentation does follow a series of presentations with respect to the Nuclear Waste Policy Act. In this respect, you will find that the high burnup program, or the extended burnup program will provide a significant cost benefit to the Waste Policy Act.

Before I forget one item that did come up with the last individual who testified, I would like to point out that in Mr. Jacobi's testimony to this subcommittee in 1983, the Westinghouse position—by the way, I believe Mr. Jacobi is in charge of the fuel division at Westinghouse—Mr. Jacobi's position was that an extended burnup program should continue and that it should continue at about a $12 million a year budget level. Evidently, there is at least one faction at Westinghouse that feels fairly strongly that the program should continue and that faction is represented by Mr. Jacobi who happens to run the fuel division at Westinghouse.

I was a little concerned about coming down here at a time of budget instability and budget questioning because there is an awful lot of budget pressure at this time. However, in retrospect, I think it is very, very timely that I am here at this particular time, because the extended burnup program will save the taxpayer money. It will also save the Government money.

As far as the taxpayer is concerned, there was a letter from Mr. Brewer to Representative Ottinger, dated October 27, 1981, and there was an analysis performed by the U.S. General Accounting Office on November 18, 1981, which indicated that this program alone will save the ratepaying public $13 billion—that is with a "b" not an "m"—$13 billion through the year 2000. I don't know of very many Government programs that can boast of a cost-benefit ratio on the order of 1 to 400 to 1 to 500. That means for every $1 you spend on this program, you will save $400.

As far as saving the Government money, this program will produce less fuel. The Government, under the Nuclear Waste Policy Act, could become the custodian of a substantial quantity of spent fuel through the years. This program, with its current goals, will produce 40 percent less discharged fuel. This will have a significant impact on the timing and the sizing of Government facilities necessary to take care of spent fuel which may not otherwise be capable of being cared for at constipated utility pool sites.

It will also have an impact on the utility industry in reducing the level of constipation.

If we look at the Nuclear Waste Policy Act, the nuclear waste policy has associated with it R&D programs, and through the years, I believe that we will be talking in terms of megadollars for mitigation of a problem, taking care of the spent fuel. As I view the current proposed budget by DOE, there are zero dollars for preventing the problem.

I don't believe that this makes sense in this time of severe budget restraint. The extended burnup program represents an outstanding example of cooperative efforts between DOE, utilities, and the private sector, and was achieved by appropriate management attention. In view of the success to date of the program, it is hard for me to understand the basis for zero funding in 1985.

The letter requesting my appearance here asked me for criticisms as well as reasons for program support. Before I get into some details on criticisms, I would like to point out that this program has been under consistent budgetary pressure. This program is threatened at every budgetary cycle, and the atmosphere created by such threats is not conducive to new and innovative thinking by the very expert scientists and engineers working on the program. Let me give you some examples.

The targets for the program, the burnup targets for the program, were established in the late 1970's. We believe, as do the Europeans, that these targets, at this time, are too low. I will dwell on that a little later on.

One part of the program which we have participated in was involved with the Omaha Public Power District. There we have a fuel assembly, which is highly characterized, with a large investment in the fabrication and the irradiation of this fuel assembly. It has been taken up to 52,000 megawatt-days-per-ton burnup, and if you look at people who are fairly experienced in R&D, I think you will find a consensus that it is usually the last 10 percent of an R&D program with a high payoff. If we look at this fuel assembly, at 52,000 megawatt-day-per-ton burnup, program plans were to have it transferred to a hot cell and examined in a hot cell.

Because of very severe budget limitations and complete inflexibility with respect to programs, this fuel assembly has never been examined in a hot cell. No funds were available. This fuel assembly, again, with all of its investment in it, could very well have gone to 60,000 megawatt-days-per-ton. This was not done. Again, it was a logical extension, because of inflexibility in program funds.

Let me dwell on another area, and I don't want to get too detailed in technical matters, but I need to dwell on a few here. If we look at what is likely to be the life limiting factor associated with high burnup fuel, we feel that the life limiting factor may very well be the corrosion of the zirconium alloy which surrounds the fuel, namely, the fuel cladding, and the zircaloy structures which occur in the core structurals. Corrosion can lead to hydriding, and corrosion and hydriding are not linear with time or with burnup.

It turns out that at around 50,000 megawatt-days-per-ton, deviations from linearity occur. During the program, rather sophisticated test methods were established for determining the thickness of the oxide layer on the zircoloy cladding. A few measurements were made. Program inflexibility did not permit a data base to be established, and this data base is extremely important because it is felt that one of the life limiting factors associated with high burnup fuel is this corrosion phenomenon.

So, again, inflexibility in program, inflexibility in program funding, budgetary restraints have limited the output from very large investments in fabrication and irradiation.

Another area is fission gas release. Test reactor irradiations have suggested that there may be higher fission gas release at elevated burnups. This has not yet been seen in power reactors, but again, in power reactors, we haven't reached the kind of burnups that the targets of this program might take us to.

This may be a physical phenomenon which occurs at high burnup. I, myself, have seen bubbles in grain boundaries on fuel up around 40,000 or 45,000 megawatt-days-per-ton. I expect to see this in high burnup fuel. The extent to which this could become a limiting factor, and the program doesn't permit the flexibility to determine that.

Another example of an item which I entitle, "You won't know until you try it," has to do with the program elements associated with advanced fuels. In Arkansas, for example, we attempted, as part of the experimental portion of the DOE program, to increase the grain size of the UO-2 by including additives. The aim here was to reduce this gas release phenomenon. This resulted in an unexpected interaction between the pellet and the cladding and resulted in excessive rod elongation. Because of our reconstitutable feature in this fuel assembly, it was possible to remove those rods, put other rods in and continue the irradiation. But again, here you have an example of a phenomenon which could not be pursued to completion.

I think it makes absolutely no sense to close out advanced fuel programs which are in place, where there have been substantial investments.

I will make some comments in a few minutes with respect to program enhancement and program additions. What I have just addressed is the concept of keeping what is going, going.

Let's understand one item which I think sometimes gets lost in a numbers game. In order to commit a batch of fuel to a burnup of about 40,000 megawatt-days-per-ton, a reasonable technical individual would require bundle irradiations at about 10-percent higher and fuel rod irradiations at even 10-percent higher than that. So, to commit to a 40,000-megawatt-day-per-ton burnup, requires bundles at 45,000 and rods at 50,000. The program target, current program target for PWR's, is a 50,000-megawatt-day-per-ton batch with bundles at 55 and rods at 60. We are not there.

Second, we need new targets. The Europeans are pushing for 55 to 60,000. So, we are sitting here with an archaic target of about a 50,000-megawatt-day-per-ton burnup while the Europeans are looking at numbers up around 55 to 60. They have hands-on experience with respect to reprocessing, and it is their belief that the economic payoffs are there at these higher burnup.

A fallout from the high burnup program is the fact that in Omaha, applying the information already gained, allowing fuel to go to higher burnups, and looking at a fuel management scheme which was part of the Omaha program, the pressurized thermal shock problem which has been identified with respect to older plants, has been mitigated because we can now place fuel on the outer periphery and we can, via fuel management schemes, reduce the fluence or the flux on the pressure vessel.

I feel that there are logical program extensions. I think that we need to extend the burnup limits, we need to extend the burnups as well on well-characterized DOE fuels toward at least 60,000- to 65,000-megawatt-day-per-ton burnup. This can be accomplished with minor scope changes. It can't be done unless there is a forward DOE commitment because the utilities are reluctant to accommodate fuel management changes unless they know, in effect, that the fuel management changes are going to be needed.

There needs to be an adoption of the new inspection and test methods to improve the data base on the potential life limiting parameter, which is basically corrosion. There also needs to be more attention paid to detailed hot cell examinations on terminally discharged fuel from this program. What I am saying here basically is let's cash in on the last 10 percent payoff of the program. There is, in advanced fuels in the program, segmented fuel rods. This has been a requirement of DOE. It is a good requirement. These segmented fuel rods could allow us to run in PBF [Power Burst Facility], in Idaho, tests which cannot be run in power reactors. These are high power change tests.

We as a nation sit here sending fuel to Sweden, to Belgium, to the Netherlands for such testing. I think that the DOE project management was quite wise in requiring that advanced fuel have segments irradiated in power reactors to permit such testing. I believe that such testing should take place in the United States.

As far as the program future is concerned, I believe that we need to continue and we need to recover what has been lost. We need to reduce the inflexibility that now exists. We need to review our current goals, and where changes in goals are viable, we need to implement these changes. We need to expand the programs to involve all fuel vendors. It is my opinion that we need to start new approaches, based on current technology, by a request for proposals for new work.

In summary, I think that the importance of the extended burnup program to this Nation is extremely high. I recommend: (1) Continuation of the current program, but with long-term funding stability and increased work scope flexibility; (2) reassessment of program goals to determine proper burnup targets in light of current and future requirements and foreign competition; (3) initiation of new program elements consistent with new goals, particularly with respect to the impact of the Nuclear Waste Policy Act; and (4) encouragement of logical program extensions which maximize the information gained from large program expenditures already made.

Finally, I would like to suggest that we decide not to debate this matter each year. Let's recognize that this program is in the best interests of this Nation, and let's move ahead and maintain our world leadership in this area.

Thank you, Mr. Chairman and members of the subcommittee.

[The prepared statement of Mr. Chernock follows:]

TESTIMONY TO THE SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION OF THE U.S. HOUSE OF REPRESENTATIVES COMMITTEE ON SCIENCE AND TECHNOLOGY

by Warren P. Chernock
Combustion Engineering, Inc.
on February 9, 1984

Madam Chairman and members of the Subcommittee, I am Warren P. Chernock, Vice President Research and Development, Nuclear Power Systems, Combustion Engineering, Inc. I am here today to comment on the adequacy and administration of the Extended Burnup Program with the aim of providing the Subcommittee with an understanding of our reasons for supporting this program.

I would like to compliment the members of this Subcommittee on their foresight in supporting the Extended Burnup Program, especially in a highly difficult budgetary atmosphere. Your support has been rewarded in that this program has been successful to date and represents an outstanding example of effective cooperative efforts which are possible between DOE, the utilities and the private sector when appropriate management attention by all three parties is applied. In view of this, it is difficult to understand the DOE budget submittal for Fiscal Year 1985 in which no funds have been requested for continuing this Program.

My experience with research and development programs indicates that major benefits are generally derived from approximately the last ten to twenty percent of the effort. The first eighty percent generally positions the programs to maximize results; the remainder of the programmatic efforts provides data and results which lead to interpretations and conclusions. Thus, about eighty to ninety percent of the results are often provided by the highly leveraged last ten to twenty percent of the expenditures.

It is also my judgement that long term research and development goals require reassessment and redirection as conditions change. With respect to the Extended Burnup Program, the burnup goals were established in the late 1970's. Although the program has achieved, for the most part, fifty percent of the incremental burnup goals established at that time, the current environment suggests that these original burnup goals may be too low now.

The Extended Burnup Program has had the support of this Subcommittee. Its current progress and success is reason enough to continue, not to discontinue. The time scale of technical development is long, in comparison with political and budgetary priorities. Any successful program must be the beneficiary of continued support and stability. The support of this Subcommittee in the past has been instrumental in maintaining some form of program stability and it is my hope that your continued support and encouragement will permit, not only the completion of original program goals, but a reassessment of these goals in the light of the current environment, leading to the initiation of programmatic implementation which is believed to be in the best overall National interest.

Madam Chairman, your letter to me dated February 1, 1984, requested that I address our company's criticisms of this program as well as our reasons for supporting it. Before I respond, it might be appropriate for me to review the underlying bases of the Extended Burnup Program.

BACKGROUND

In 1977, DOE embarked on a program to improve uranium utilization in light water reactors. At the early stages of this program, it was found that extended burnup was the single most effective means of accomplishing this objective. In addition to improving uranium utilization, it was found that significant economic benefits are derived from long (18 month) fuel cycles and from reductions in requirements for fresh fuel fabrication, transportation and spent fuel storage; in addition, waste disposal requirements would be reduced. Thus, Combustion Engineering, as well as other fuel suppliers, participated in DOE-sponsored programs aimed at the development of high burnup fuel.

Electric power generation costs can be reduced by lengthening the time between reactor refuelings and by increasing the lifetime of the fuel. Implementation by the utilities of these new technologies, when available, would reduce the cost of power to the consumer.

The two separate improvements include increasing the time between refuelings (increasing cycle length) and increasing the life of the fuel (increasing fuel burnup). Although either of these improvements can be implemented separately, greatest overall benefits are obtained when long cycles are used in conjunction with high burnup.

Increasing the cycle length results in reactors being refueled less often and is economically advantageous since more expensive replacement power from fossil fuels must be used during the period the reactor is shutdown for refueling. Increase in cycle length can be achieved without increased burnup because implementing a longer cycle is technologically straightforward. However, high burnup fuel requires substantial technological advancements and in-reactor developments which are the bases of the DOE Extended Burnup Program.

When both longer cycles and extended burnup fuel are employed, economic savings are realized both from reduced replacement power costs (longer cycles) and from reduced fueling costs (extended burnup) and provide a net reduction of about 3 percent in uranium requirements and about a 40 percent reduction in the quantity of fuel to be fabricated and discharged after each cycle. The reduction in the volume of discharged fuel should ameliorate the problem of spent fuel storage at reactor sites, where storage rack capacity is limited, and should reduce the demand on DOE for storage requirements under the new Nuclear Waste Policy Act.

The DOE-sponsored development programs address, primarily, the development of high burnup fuel.

Combustion Engineering, Inc. (C-E) joined DOE in demonstrating extended burnup fuel improvements. Our "entrance fee" for participation included "head end" transfer of related proprietary information to DOE. These "head end" transfers of proprietary technology have been made public, with our concurrence, on the presumption that the Extended Burnup Program would continue to completion. A further requirement of utility participation was imposed by DOE and endorsed by C-E.

One program was initiated with Omaha Public Power District (OPPD) to develop extended burnup and low leakage fuel management for C-E's 14 x 14 fuel design at the Fort Calhoun reactor. A second program was started with Arkansas Power and Light (APL) to develop extended burnup for C-E's 16 x 16 fuel design at the Arkansas Nuclear One Unit 2 reactor.

The OPPD program has essentially been completed and has given C-E added confidence to offer standard C-E 14 x 14 fuel reloads to burnups significantly higher than those at the time the program was initiated. The APL program has not yet achieved major burnup milestones. Continuation and completion of this program will enable the potential of achieving additional burnup extension for alternate fuel designs by the end of 1987.

CRITICISMS

The Extended Burnup Program has been under budgetary pressure for a number of years and as a result, an "atmosphere" has been created where nothing new or innovative can be encouraged or pursued.

Although performance to date on this Program represents one of the most successful DOE projects during its timeframe, its future has been threatened at almost every budgetary cycle in recent years. Successful program performance is a reason to continue a program; it should not be an argument for premature cancellation. Funding stability is necessary if any program is to succeed. The fact that success so far is being achieved, even under these adverse budgetary conditions, is a tribute to members of this Subcommittee who have provided the legislative leadership to restore some of the funds when they were needed.

The major criticism of the adequacy and administration of DOE's Extended Burnup Program is the inflexibility relative to substantive technical workscope changes within the programs or the ability to propose new work. Several compromises were necessary in the course of executing both the OPPD and APL programs by C-E due to the inability to make major modifications in contract workscopes over the last three years. The uncertainty in budget levels and continuity of the programs provided a disincentive to cooperating utilities to make longer term commitments for irradiation testing and irradiated fuel examinations.

Problems relating to funding instability on this Program are numerous. During the course of executing the various programs, it became apparent that further extension of workscope on existing programs to even higher burnups would have been desirable. For example, extending the OPPD irradiations would have allowed the achievements of very high burnups (approximately 60 MWd/Kg) within reasonable time schedules on extremely well characterized fuel assemblies. Fuel performance data at these higher burnups could have been attained with extreme efficiency since the irradiations were already part of an ongoing program. Not only were these irradiations terminated after a fuel assembly average burnup of 52 MWd/Kg but the hot cell examination, in the original program, was cancelled as a result of insufficient funds. As

I indicated earlier, in many instances, the most significant technical results and conclusions can be derived from the last ten to twenty percent of program funding. Cancellation of the hot cell examinations has resulted in the loss of this important information.

The Extended Burnup Program at APL is continuing and has not yet achieved major burnups. Expenditures through the current Fiscal Year are approximately 55 percent of the total contract value. The fuel has been fabricated, is under irradiation in a power reactor and has achieved an assembly burnup of about 19 MWd/Kg. Thus, there are no extended burnup data available. Cancellation now will lose the entire investment to date. Later reversal of the decision to cancel would lose at least four years of valuable lead time.

In addition to recognizing the potential value of extending existing programs, technical fallout from these programs indicated the need to explore other areas. New program efforts would be of high overall value to obtain additional information on the corrosion life limit of Zircaloy-4 cladding with various thermomechanical treatments. The development and testing of burnable absorber concepts other than Gd_2O_3-UO_2 would be beneficial in further improving fuel utilization in PWRs.

One specific example of an area where valuable information may not be obtained is subsequent transient testing of fuel irradiated as part of the DOE Extended Burnup Program. All of DOE's programs on advanced fuels included the irradiation of segmented fuel rods in order to obtain prototypic samples which could readily be tested at conditions not possible in a power reactor. C-E, on its own, has made very significant progress in understanding fuel performance from segment irradiation programs initiated in 1973. The DOE segmented fuel program is a valuable resource but there may be no payoff. The budget limitations and inability to initiate new work has prohibited even the detailed planning of subsequent test reactor irradiations on the DOE segments to obtain data, for example, on the transient performance of standard and advanced design fuels. Of particular interest is the kinetics of fission product release during short time power excursions. In addition, during the course of the programs, new inspection techniques were developed and could have been applied more extensively had workscope changes or new programs been a viable option. An example is the ability to directly measure the corrosion film thickness on Zircaloy clad fuel rods to assess potential corrosion life limits. This technique became generally available during the period after initiation of the DOE Extended Burnup Program. This technique was applied in a few cases but not sufficiently widespread to add significantly to our understanding of corrosion as a life limit.

Finally, there appears to be a lack of adequate planning to ensure that former goals are reassessed to determine their viability in today's climate. There is reason to believe that the original burnup targets are too low and that foreign competitors are aiming at higher burnups which could impact our world leadership in this technology area. The continuous threat of funding cutoffs and the requirements that no new programs be initiated have removed this important prerogative from consideration.

REASONS FOR PROGRAM SUPPORT

A summary of our reasons for program support was provided in my testimony to this Subcommittee on March 17, 1982. Since that time, a number of additional factors for strongly supporting this Program have been identified and are summarized below:

1. General

Nuclear systems are highly interrelated. Improvements in one area are likely to lead to improvements in other areas as well. For example, the Extended Burnup Program was initiated on the basis of improvements in uranium utilization. Results of the Extended Burnup Program at OPPD has provided an added benefit in permitting fuel management arrangements which helped reduce the pressure vessel neutron fluence and, thus, mitigate concerns over pressurized thermal shock (PTS), which is a current NRC concern for older plants.

In addition, the large potential reduction in the number of fuel assemblies discharged per unit time as a result of the extended burnup developments should provide significant financial benefits to DOE in the timing and sizing of facilities for fuel storage required by the Nuclear Waste Policy Act of 1982. In this latter respect, it is somewhat ludicrous that DOE appears to be prepared to expend large sums of taxpayer and utility ratepayer funds to accommodate spent fuel after it is discharged but appears to be unwilling to reduce the amount of material to be discharged, especially when the costs associated with minimizing discharge is extremely small in comparison to the custodian costs. The concept of prevention versus mitigation is important here since mega-dollars are involved in mitigation. The cost/benefit ratio of the Extended Burnup Program can be justified on this basis alone.

2. Need for Government Sponsorship

Although there is significant economic incentive to use extended burnup and other fuel cycle improvements, it nevertheless appears that they are unlikely to be fully implemented without DOE development support. The primary reason for this is that the development costs and performance risks are sizeable and that the economic benefits accrue solely to the operating utility which must in turn pass these savings on to its ratepayers. For the fuel vendor, there is a disincentive since fabrication volume is reduced while warranty risks may be increased.

The implementation of high burnup results in fewer fuel assemblies being sold to utilities which is a direct disincentive for vendors to offer the high burnup capability on their own. Although the fuel vendors are exposed to some competitive pressure to increase warranted burnup, this represents an added risk which is aggravated by reduced fabrication volume.

The benefits of increased burnup accrue directly to ratepayers, but this benefit would not occur or would at least be delayed without Government sponsorship. Since the benefits of fuel cycle improvement programs accrue to the public, it seems appropriate that the public underwrite the development costs.

The potential economic benefits to utility ratepayers are substantially greater than the cost of continuing or expanding the Program. Both the U.S. Department of Energy and the General Accounting Office have performed cost benefit studies which indicate that the cumulative benefit to the general public of fully implementing extended burnup would be approximately $13 billion (1981 dollars) through the year 2000. Considering the small cost of continuing and expanding the Program, the cost benefit ratio is about 1:300. This very low cost-to-benefit ratio is considerably smaller than that typically encountered in Government-funded development work.

Since the incentive for the fuel suppliers or the utilities themselves are unlikely to be sufficient to continue development of extended burnup at the pace which has been established by the DOE Program, the benefits of extended burnup are likely to be substantially reduced if the DOE Program is terminated or substantially reduced. Further development, if any, will proceed at a much slower pace reflecting the lack of incentive to either the fuel supplier or the utilities. With a much slower development schedule, it is likely that foreign fuel suppliers would close the gap in the development of extended burnup fuel and possibly obtain a competitive advantage over U.S. suppliers in third countries.

3. POTENTIAL FOREIGN COMPETITION

In 1982, when I last testified to this Subcommittee, the threat of foreign competition was noted. In the interim time period, several key changes have occurred which have resulted in an acceleration of efforts to extend fuel burnup on the part of the Europeans. The real costs of commercially reprocessing fuel are now apparent and is significantly higher than anticipated several years ago in Europe. This is now the primary driving force for European utilities to demand higher burnup fuel. The Germans, specifically KWU/RWE, are implementing increase in fuel burnup and now have parity or lead in improving fuel utilization compared to the U.S. RWE has discharged at least one batch of fuel with burnups over 40,000 MWd/Kg from one of their Biblis reactors.

The French, after a late start, are becoming technologically very sophisticated in the fuel area and have a very active and well-funded Government-supported program to extend fuel burnups to levels well beyond those contemplated in the U.S.

In the event Government sponsorship of improved fuel utilization programs is reduced or discontinued, U.S. implementation of extending burnup will unquestionably slow down and we will lose the lead to foreign competition. This is due to the disincentive for the U.S. nuclear industry to continue to resource high burnup programs and a potential reluctance on the part of utilities to push burnups to higher levels without adequate development, usually in the form of lead test assemblies and selective continued irradiation of partial batches.

It is interesting to note that essentially all of the design features being considered in foreign programs have been considered and/or are under development as part of the existing DOE Extended Burnup Program. Thus, the U.S. has provided the concepts for extending fuel burnup upon which foreign development is based. It would be truly unfortunate if foreign fuel suppliers were to fully develop these ideas while U.S. suppliers retreated from an aggressive development program due to lack of Government funding, thereby placing U.S. vendors at a commercial disadvantage relative to their foreign counterparts in third countries.

4. IMPACT OF EXTENDED BURNUP ON WASTE MANAGEMENT

The Nuclear Waste Policy Act of 1982 established the comprehensive national program for the interim storage and permanent disposal of spent fuel discharged from commercial nuclear power reactors. Although comprehensive and stipulating how spent fuel will be managed, the Act does not contain provisions designed to encourage reduction in the amount of spent fuel generated by reactors. From a waste management perspective, extended burnup is important because the amount of spent fuel discharged from a nuclear reactor is inversely proportional to the fuel burnup. For example, a reactor will discharge 40 percent less fuel if its discharge burnup is 50,000 MWd/Kg than if its discharge burnup is 30,000 MWd/Kg. Thus, the amount of fuel that the Government may have to store can be significantly altered by the fuel discharge burnup that the nuclear industry has adopted. It is acknowledged that the decay heat per unit weight of fuel is greater for extended burnup than for conventional burnups. However, the net result of the lower quantities of spent fuel and the higher decay heat rates result in a reduction in the total heat loading required of a spent fuel repository. Even this negative aspect of the higher decay heat of extended burnup can be readily eliminated by longer interim storage of the spent fuel at the reactor site to allow the decay heat rates to decrease to near those of standard burnup fuel at the time of transfer to the repository.

Adequate completion of the current Extended Burnup Program and extension of its goals to encompass the current environment should be of substantial financial benefit to DOE in planning for the timing and sizing of facilities necessary to accept spent fuel required by the Nuclear Waste Policy Act. In order for this planning to be effective and realistic, the future of the Extended Burnup Program must be identified, placed on a high priority and removed from the threat of zero funding or less-than-bare existence funding during each budget review.

RECOMMENDATIONS

On the bases of the importance of the Extended Burnup Program to this Nation, I strongly urge this Subcommittee to continue its support of this Program via recommendations for funding in Fiscal Years 1985 through 1987 for the following:

1. Continuation of the current Program but with long term funding stability and increased workscope flexibility.
2. Reassessment of Program goals to determine proper burnup targets in light of current and future requirements and foreign competition.
3. Initiation of new Program elements consistent with new goals, particularly with respect to the impact of the Nuclear Waste Policy Act.
4. Encouragement of logical program extensions which maximize the information gained from large program expenditures already made.

WARREN P. CHERNOCK

Warren P. Chernock, Vice President, Research and Development, has been with C-E since 1956 and has served in prior capacities as Manager of Metallurgy, Director of the Nuclear Laboratories and Vice President of Development. He has served in various positions in industry and education. Mr. Chernock has been associated with the Argonne National Laboratory and the Massachusetts Institute of Technology where he was a Visiting Associate Professor of Nuclear Engineering. He has been on the staff of The Hartford Graduate Center of Rensselaer Polytechnic Institute since 1956 as an Adjunct Professor and is now Chairman of the Metallurgy Department. These university positions are concurrent with his position at C-E. Mr. Chernock was a U.S. delegate to the First and Second U.S.-Japan Exchange Meetings on Nuclear Ceramic Fuel in 1963 and 1964. In addition, Mr. Chernock was selected by the U.S. Atomic Energy Commission to present papers at both the Third and Fourth United Nations International Conference on the Peaceful Uses of Atomic Energy held in Geneva in 1964 and 1971. In 1982, Mr. Chernock represented the American Nuclear Society as a U.S. delegate to the International Atomic Energy Agency General Conference held in Vienna. He is Chairman of The Metal Properties Council Subcommittee on Nuclear Materials and a Member of the Council's Technical Advisory Committee. In addition, Mr. Chernock is Chairman of the University of Chicago Review Committee of the Argonne National Laboratory Reactor Analysis and Safety Division. He is a member of the American Society for Testing and Materials and a Fellow of the American Nuclear Society and the American Society for Metals. Mr. Chernock holds several patents on fuel elements and has authored numerous papers in the area of nuclear materials.

Mr. **Valentine**. Thank you very much, sir.

You are our last witness and I want to recognize my esteemed colleague, Mr. Walker, and let him know, and if anybody here would like to certify that we have been asking his questions for him—however, before he makes his statement or asks whatever questions he deems appropriate, I feel that I need to make one observation.

We heard from this distinguished witness and we hear so often in this committee and other places in the Congress as to what is being accomplished by our friends and, in some instances, our adversaries overseas in the area of scientific achievement and all great and wonderful new accomplishments, especially among the Japanese. You just mentioned, I believe, the Swedish and the Dutch.

I wonder what we could accomplish in this country, and I make this observation with respect to our wonderful Japanese friends and allies, what we could accomplish in this country if we had someone else who, with the strength to provide a defense umbrella, if we did not have to put the billions of dollars in defending ourselves and them, how we could use the billions of dollars we spend, such as $1 billion to build one airplane? Why, I don't know. We could double the salary of all schoolteachers in North Carolina with that, but that is what it costs. How many wonderful and great and humanitarian things we could do for ourselves and for our friends if we were, say, like our Japanese friends, and had some great power that was protecting us as we are them.

I make that observation because I am in the Chair and nobody can respond.

I recognize my good friend, Mr. Walker.

Mr. **Walker**. I thank you very much, Mr. Chairman, and I am pleased to know that my questions were being asked while I was up receiving a graduate education in nuclear energy, particularly as it relates to Three Mile Island, from Admiral Rickover. He was in my office today talking about Three Mile Island, and I appreciate the fact that you were able to carry on despite my absence.

I do have a statement here, Mr. Chairman, that I would ask be put at the appropriate place in the record for a statement that is not completely read, and I just want to make one observation that is in that statement. However, I would like to get on the record.

Mr. **Valentine**. Without objection, so ordered.

Mr. **Walker**. I noticed in the testimony that is to be presented here today that the West Valley cleanup is being presented as a nuclear success story. Let me just say that I have some very serious reservation about that program. I was here when we first authorized the cleanup, and I served as the ranking member on the Investigations and Oversight Subcommittee when we looked into the original agreement between the Department of Energy and the State of New York.

It appears to me that the West Valley program is about to go far beyond what this committee or Congress intended or authorized in it, and I expect that we will be looking into this whole area with a very critical eye.

I thank you very much for yielding, Mr. Chairman.

[The prepared statement of Congressman Walker follows:]

PREPARED STATEMENT OF REPRESENTATIVE ROBERT S. WALKER

Good Morning, Madame Chairman. Let me join you in welcoming our witnesses here today. Our hearing today marks the end of our first week of hearings on the President's fiscal year 1985 budget request for the Department of Energy research and development activities for the coming year.

We have had a number of witnesses who have given us thoughtful testimony concerning the progress and accomplishments of present programs. We have also heard a great deal of testimony which indicates that there are a number of things which this Committee would like to see accomplished, and which are widely supported in the nuclear industry and the academic community.

The first of these is obviously the Inherently Safe Reactor concept which this Committee strongly supports. Despite the claims from some nuclear proponents that the current state of the industry is merely a passing problem, we firmly believe that if America is to preserve the nuclear option for the future, we must move at once to make fundamental changes in the way the nuclear option is structured. This Committee does not have jurisdiction to address basic problems of licensing and regulation. We do not foresee any legislation on that topic moving in the present Congress. And there is nothing we can do at this time to change that since we have no jurisdiction in that area.

What we can do, and what we must do, is move the Department of Energy toward developing a new generation of reactors which are safe, so safe that we will never again see a Three Mile Island type of accident. We also want to see this new generation of reactors become the first of line of common designs, built in a factory, with the same people working on each in the same way that people on an assembly line all do the same things to each unit that comes down the line. In that way we will design in some quality control, and we will also reduce costs and make it far easier to get licensing for each new unit as it comes off the line.

We detected yesterday that there is restrained support for this concept within the Department of Energy. I would suggest that they carefully read the transcripts of these hearings. What we are saying is that we can move a program to develop an Inherently Safe Reactor through the Congress, but that we have serious doubts we can protect a budget that devotes more that 85 percent of all advanced reactor funding to the breeder program.

Finally, as I read the testimony to be presented today I noticed that the West Valley clean up is being presented as a nuclear success story. Let me just say that I have some very serious reservations about this program. I was here when we first authorized the clean up and I served as the ranking member on the Investigations and Oversight Subcommittee when we looked into the original agreement between DOD and the State of New York. It appears to me that the West Valley program is about to go far beyond what this Committee or the Congress intended or authorized. I expect that we will be looking into this with a very critical eye.

Thank you, Madame Chairman.

Mr. VALENTINE. Thank you very much, Mr. Walker.

Let me thank, again, all of you who came here today and made these fine presentations.

This committee will now stand in recess until 1 p.m. this afternoon when we will hear from Department of Energy witnesses.

[Whereupon, at 10:34 a.m., the subcommittee recessed, to reconvene at 1 p.m.]

AFTERNOON SESSION

Mrs. LLOYD. The Subcommittee on Energy Research and Production will come to order.

Good afternoon, ladies and gentlemen. As I explained this morning, we will now be receiving testimony from the Department of Energy on their proposed budget for fiscal year 1985 for the commercial nuclear waste research and development program, the nuclear waste fund program, the remedial action program, the West Valley demonstration program, and the light water reactor extended burnup program.

Our witnesses this morning were from outside of the Department of Energy. They provided us with a number of criticisms and comments which we shall explore with the Department during this session.

Mr. Michael Lawrence and Dr. Frank Coffman are here today to represent the Department. Mr. Lawrence is the latest Acting Director of the Office of Civilian Radioactive Waste Management. We welcome you here, and we certainly mean no ill reference, Mr. Lawrence, to you when we make the observation that this Office has had so many acting directors' it's a wonder that the waste fund program hasn't suffered more. Dr. Coffman is the Director of the Office of Terminal Waste Disposal and Remedial Action whom we are very pleased to have with us again.

I noted this morning that the Department recently published its first draft of volume 1 of the mission plan which sets forth the major assumptions to be used by the Department in their implementation of the nuclear waste fund program. Mr. Walker and I recently sent a letter of comment to the Department on this draft, but have not yet received a reply. Since it is relevant to this afternoon's session, I ask unanimous consent that this letter be added to the record immediately following this opening statement and, without objection, it is so ordered.

Although this volume 1 draft does not satisfy the requirements of the act, it does set forth a number of policy issues which must be discussed in Congress. We do not take exception to many of these issues, but of primary concern to this subcommittee is the failure of the Department to comply with the scheduled milestones set forth in the act. This is also an issue of prime concern to the utilities who testified this morning.

On the West Valley project, the subcommittee wishes an explanation of whether or not all of the decontamination work at the facility is necessary to conduct the solidification effort; and, if not, whether the State of New York will pay for the excess. We also want assurances that New York is paying its share of the project as required by the law.

And finally, the subcommittee wants to know DOE's estimate of the funds needed to complete the light water reactor extended burnup program.

[The letter mentioned above follows:]

DON FUQUA (Fla.), Chairman

ROBERT A. ROE, N.J.
GEORGE E. BROWN, JR., CALIF.
JAMES H. SCHEUER, N.Y.
RICHARD L. OTTINGER, N.Y.
TOM HARKIN, IOWA
MARILYN LLOYD, TENN.
DOUG WALGREN, PA.
DAN GLICKMAN, KANS.
ALBERT GORE, JR., TENN.
ROBERT A. YOUNG, MO.
HAROLD L. VOLKMER, MO.
BILL NELSON, FLA.
STAN LUNDINE, N.Y.
RALPH M. HALL, TEX.
DAVE MC CURDY, OKLA.
MERVYN M. DYMALLY, CALIF.
PAUL SIMON, ILL.
NORMAN Y. MINETA, CALIF.
RICHARD J. DURBIN, ILL.
MICHAEL A. ANDREWS, TEX.
BUDDY MAC KAY, FLA.
TIM VALENTINE, N.C.
HARRY M. REID, NEV.
ROBERT G. TORRICELLI, N.J.
FREDERICK C. BOUCHER, VA.

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515
(202) 225-6371

LARRY WINN, JR., KANS.
MANUEL LUJAN, JR., N. MEX.
ROBERT S. WALKER, PA.
WILLIAM CARNEY, N.Y.
F. JAMES SENSENBRENNER, JR., WIS.
JUDD GREGG, N.H.
RAYMOND J. MC GRATH, N.Y.
JOE SKEEN, N. MEX.
CLAUDINE SCHNEIDER, R.I.
BILL LOWERY, CALIF.
ROD CHANDLER, WASH.
HERBERT H. BATEMAN, VA.
SHERWOOD L. BOEHLERT, N.Y.
ALFRED A. MC CANDLESS, CALIF.
TOM LEWIS, FLA.

J. H. POORE
Executive Director
ROBERT C. KETCHAM
General Counsel
DAVID S. JEFFERY
Minority Staff Director

January 11, 1984

Honorable Donald Paul Hodel
Secretary
Department of Energy
Washington, D.C. 20585

Dear Mr. Secretary:

Thank you for promptly providing the Committee with the first volume of the draft mission plan for the Nuclear Waste Program initiated pursuant to the Nuclear Waste Policy Act of 1982 (Waste Act). We have several comments that pertain to issues which may arise during the FY 1985 budget review process and would therefore like to bring them to your attention.

We are most concerned that the Department has slipped many of the deadlines set forth in the Waste Act. We recognize that the operating date for the first repository remains the same in the draft mission plan as in the Waste Act, but almost all other milestones have been slipped. Such cumulative slippages will make it increasingly difficult for the Department to achieve the stated repository operating date. We thus believe that more effort should be made to achieve the individual milestones set forth in the Act. For instance, perhaps some time could be saved by reducing the site characterization process to the absolute minimum required to make a decision on a site, while relying on the Test and Evaluation Facility (TEF) program for the collection of additional necessary information to enable licensing decisions to be made. The Department should also consider steps to expedite internal decision-making. We recognize that these actions will not be universally popular yet they would be consistent with Congressional intent to have the law executed as it is written.

We believe that more discussion is needed in the mission plan of the role and importance of the TEF. Section 217(a) of the Waste Act identifies eight purposes of the TEF, including "to provide a means of identifying, evaluating, and resolving potential repository licensing issues...." The draft plan implicitly acknowledges that the site characterization process may not provide "all necessary information and data to support licensing..." (Draft plan at 2-10). We believe that this is an important role for the TEF that should be emphasized in the plan. This role and the other seven purposes identified for the TEF should be more fully explained in section 2 E. 2. (beginning on page 2-11) of the report. Please refer to the Science and Technology Committee's Report #97-411 Part I, pages 33-34 as a basis for a detailed understanding of what the Committee intended the TEF to accomplish. We understand that the omission of some of these goals for the TEF was not intended to imply that the TEF would not serve these purposes, but was done merely as a convenience in summarizing the goals of this facility. We therefore fully support, as consistent with the Waste Act and the Committee views, the Department's plans for the construction, operation and utilization of this facility.

As you know, we have previously expressed our support for credits to utilities for reprocessing spent fuel. The draft plan states that the Administration supports reprocessing and that DOE "retains the capability to accept high-level wastes from reprocessing...and will consider any...proposals from industry to reprocess spent fuel" (Draft plan at 2-5). We continue to believe that conservation of energy and resources through reprocessing spent fuel is not only a wise public policy but also, that it would result in a significantly reduced environmental burden for the disposal program. These should be reasons enough for the Department to provide a credit for the disposal of wastes rather than spent fuel, thus encouraging reprocessing. We believe the plan should discuss this issue.

The Committee supports the Department's decision to investigate the use of "all-purpose" nuclear waste containers. This concept, introduced by the Tennessee Valley Authority, has the potential to improve safety and decrease costs. We think the Department has made the appropriate decision relative to the development of this type of nuclear waste container.

We bring to your attention the fact that either the affected State or the affected tribe (not both) may file a notice of disapproval of the President's site designation. See Sections 116(b)(3) and 118(a) of the Waste Act. Thus, the word "and" should be deleted from the first sentence on page 3-A-42. If the Department has ascribed a different meaning to the above quoted sections of the Waste Act, we would appreciate being so advised.

We suggest that the addition of "authorization and" before "appropriation bills" on page 3-A-11 would be appropriate. The Department's authority to conduct its waste program has also been through "authorization acts."

Should there be any questions concerning our comments, please contact us or the following Subcommittee staff: Mr. Louis Ventre, Jr. for Mrs. Lloyd on 225-2981, or Mr. David Clement for Mr. Walker on 225-8152.

Sincerely,

Marilyn Lloyd
MARILYN LLOYD
Chairman
Subcommittee on Energy
Research and Production

Bob Walker
ROBERT S. WALKER
Ranking Republican Member
Subcommitte on Energy
Research and Production

LW:Vdm

Mr. **Lloyd**. Before we begin I would like to ask for Mr. Walker's statement but, since he is not here, he cannot deliver his opening remarks.

Our first witness is Mr. Michael Lawrence in his first official appearance before us. He will be joined at the witness table by Dr. Frank Coffman, who is a familiar face to the subcommittee, whom we are very pleased to welcome again here today.

Gentlemen, after I make another vote you may proceed as you wish and your entire written statements will be made a part of the record following your oral presentations, and we will stand in recess for approximately 10 minutes.

[Short recess taken.]

STATEMENT OF MICHAEL J. LAWRENCE, ACTING DIRECTOR, OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT, DEPARTMENT OF ENERGY

Mr. **Lawrence**. Madam Chairman, it is a pleasure to be back and this time to be in the lead seat.

Mrs. **Lloyd**. I think you are filling the role very well.

Mr. **Lawrence**. Well, thank you very much. I appreciate that, and it is a pleasure to present to the subcommittee the first budget which has been prepared by the Office of Civilian Radioactive Waste Management. I have a lengthy testimony on that budget and request that it be submitted and put in the record.

Mrs. **Lloyd**. Without objection, your complete testimony will be made a part of the record, so you may proceed as you wish.

Mr. **Lawrence**. OK. Madam Chairman, instead of going through our budget and highlighting the dollars and the activities that we're going to do, I'd like to address several of the issues of interest which you raised in your opening remarks and which were in the announcement for this meeting.

Mrs. **Lloyd**. Please proceed.

Mr. **Lawrence**. The budget we have and the programs I'll be talking of to cover the nuclear waste disposal fund which, for $328 million in fiscal year 1985, will cover all of our repository activities, monitored retrievable storage activities, and the management of the fund, plus $27.6 million for civilian radioactive waste research and development activities which deal with our spent fuel demonstration programs, our alternate disposal technologies, and the various studies we have for the waste management program.

Several items of interest have been raised by yourself and others concerning our program which I'd like to deal with. The first deals with the Department's commitment to the milestones which were in the Nuclear Waste Policy Act, and I can assure you that the Department is extremely serious about the schedules and the milestones laid out in that act, and it is trying to lay out and perform a program which will meet both the spirit and the intent of the act, plus meet those milestones. I think indicative of this is the fact that, in our draft mission plan which you commented on, our fundamental objective is to begin accepting commercial radioactive waste for storage management and disposal January 31, 1998. We have a contractual requirement with the utilities to do that; we believe it's a cornerstone of the act in terms of laying out responsibilities between the private sector and the Federal Government, and we believe we are laying out programs and looking at options to insure that that is met.

Turning to the first year of our program, we did have a number of very ambitious milestones to meet and I think the record shows that we've done quite well. We didn't meet all of them, however. We've identified nine potentially acceptable sites for the first repository and we've had hearings at those sites; we've also informed 17 States that they have areas under consideration for a second repository. All of the requirements in the act for both fund management and contracts and fee collections have been met, so all nuclear utilities currently are under contract and are paying into the waste disposal fund.

The monitored retrievable storage program, which we look at as a parallel program to the repository and a backup to insure that we can meet the 1998 date, is proceeding on schedule. We've issued the R&D plan, which was required by the act, in June of this year; we selected the major architect-engineer contractor for the program; and just recently we selected the two concepts which will be developed for the MRS proposal. The sealed storage cask concept is our prime one, and our field dry well concept is the backup for the MRS proposal. This decision was made by our field office and our program managers, but also involved utilities and industry representatives and also congressional staff representatives.

The spent fuel cooperative demonstrations provided for by the act are proceeding extremely well, and I believe you had some testimony concerning that this morning. We have selected two utilities, VEPCO and Carolina Power & Light, for dry storage cask demonstrations, and northeast utilities for rod consolidation demonstration. In addition to this we are working on demonstrations on rod consolidation and dry storage with TVA, and are coordinating all of our activities in this area with NRC to insure that the utilities have licensable storage technologies to insure that they can meet their storage needs.

Mrs. LLOYD. What kind of work are you doing with TVA?

Mr. LAWRENCE. There is a cooperative rod consolidation program going on at Brown's Ferry. Plus, in the area of dry storage, two casks—one foreign-manufactured cask, is being provided to TVA by GNS at Brown's Ferry, plus the Department has purchased an REA cask which is undergoing testing right now with GE in Morris, Ill., and will be sent to Brown's Ferry for loading with fuel at that site. And this is providing licensing data and heat transfer data to support dry storage technologies.

Mrs. LLOYD. Very fine.

Mr. LAWRENCE. The act also provides for us to enter into agreements on spent fuel storage and disposal with nuclear nonweapon States. We have put out a Federal Register notice on that and have had responses from four countries and informal responses from others interested in pursuing that activity with us.

One of the activities which was late in meeting its milestone in the act—but we think has proceeded well—was the issuance of guidelines for generic siting of repositories. The act called for that to be completed in July 1983, and we missed that date. The reason we missed it was, after we put out draft guidelines last February, we had 60 days of comments; we received over 2,000 comments at that time. We had public hearings, and our review of those comments indicated that significant additional work needed to be done. Consequently, we had another round of public comments on the guidelines; we had 29 individual and collective meetings with the States and other Federal agencies on the guidelines. And ultimately, after five drafts of those guidelines, sent them to NRC in November 1983 for their concurrence as required by the act. They now have those guidelines; we testified before them in January concerning their accuracy; and their current plans are to act on the guidelines by the end of April. That is a critical activity in the program because, with those guidelines, we can then proceed to do environmental assessments on the sites we intend to nominate, and be able to nominate at least five sites and recommend three for characterization by January 1, 1985, as required by the act. We do anticipate meeting that date.

Once that date is met, however, the next milestone in the act does cause us problems, and that is that after the characterization of the sites, we are required to recommend to the President the first repository site in 1987. However, our analysis of what is required in order to characterize the site indicates that that date most likely will not be met. In order to get permits at those non-Federal sites at which characterization would take place, that could require up to 1½ years to get those legitimate permits. The sinking of exploratory shafts just to get at depth to conduct experiments could take from 1 to 1½ years; for site testing—which ultimately is dependent upon a site characterization plan which we have to reach agreement with NRC on as to the amount of data and the type of data that you need to get to support a license—our indications are, in discussions with them, that it could take from 1 to 3 years to collect sufficient information to support our licensing request.

Finally, after all that data is collected, we have to issue an environmental impact statement on our selection. As we all know, that can be a very lengthy, process although we've only allowed approximately 6 to 8 months in our schedule for that. Subsequently, instead of being able to recommend the first repository site in 1987 or 1988, as provided by the act, a 1-year delay, it now appears to us as if December 1990 may be the earliest we could recommend that site and send the recommendation to the President.

Nevertheless, we feel that there are several different options for us to still be able to meet a 1998 repository date and to be able to begin accepting waste at that time. These options will be explored in the mission plan when it comes out for its formal draft on April 7. We recognize the initial draft which was sent to the committee, and which we appreciate your comments on—our response is on its way to you, it's in the Department right now for final concurrence, although I must add that that response is primarily an acknowledgement of your letter and notes that we received it. We were not going to respond specifically to each of the points until we have had an opportunity to get all of the comments on the mission plan which we're doing right now, and have made revisions to the draft. I would like to indicate that we have gotten a number of very good comments on the role of the test and evaluation facility, the need for more specificity, the need to address various options for getting to where we have to be in the plan; these will all be addressed, and we do anticipate having the draft out in April 1984, as required by the act.

Finally, I would like to make a note about organization and, I guess, pick up on your comments about the acting directors. Several times this week Secretary Hodel has noted that it has personally been an embarrassment that he has not named a permanent Director, or that we have not gotten a permanent Director for the Office. As you know, it requires Presidential approval and submitting it to the Senate for confirmation. He has indicated that a name is at the White House now, and he hopes to have the approval to announce that name in the next several days. He's anxious to do that. Nevertheless, both Bob Morgan, who was the former Acting Director of the Office, and myself have enjoyed complete cooperation from the Department. We do have access to the Secretary, almost on a daily basis; he has been extremely supportive and, if anything, I think perhaps the Department has gone overboard to be supportive of us because of this acting role. So we do feel that the program, although it doesn't have the stability of a permanent Director yet, it has made—has had a number of accomplishments, made a number of milestones, and we look forward to continue working with the members of the committee, and the staff as we move ahead on the program and hopefully meet all the spirit and the intent of the act.

I'd be happy to answer any questions you have on that.

[The prepared statement of Mr. Lawrence follows:]

PREPARED STATEMENT OF MICHAEL J. LAWRENCE, ACTING DIRECTOR, OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT, DEPARTMENT OF ENERGY

Madam Chairman and Members of the Subcommittee:

I am pleased to appear before you today to discuss the Department of Energy's (DOE's) Fiscal Year 1985 commercial nuclear waste management and spent fuel storage budgets and programs. The FY 1985 budget represents the first budget formulated by the Office of Civilian Radioactive Waste Management, recently established under the Nuclear Waste Policy Act of 1982.

The FY 1985 budget presents an integrated picture of programmatic activities including: repository deployment, monitored retrievable storage development and fund management which are specifically financed by fees collected from utilities and placed into the Nuclear Waste Fund; and, research and development activities not eligible for financing under the Nuclear Waste Fund, including research and cooperative agreements on spent fuel and research on alternative disposal concepts. These latter activities are funded under Energy Supply Research and Development in a program entitled Civilian Radioactive Waste Research and Development (R&D).

The FY 1985 budget request for obligational authority funded by the Nuclear Waste Fund is $327.669 million.[1] This budget request is summarized in Table 1. The FY 1985 Departmental budget request for Energy Supply R&D, which covers activities not eligible for funding under the Nuclear Waste Fund, is $27.64 million. This budget is summarized in Table 2.

The $327.669 million requested will be used to fund the activities under the direction of the Office of Civilian Radioactive Waste Management. These activities are fashioned on the fundamental objective of the Nuclear Waste Policy Act of 1982 (NWPA), which is:

> "to accept high-level radioactive waste for safe management, storage and permanent disposal on a firm schedule, beginning not later than January 31, 1998."

By achieving this fundamental objective and implementing an appropriate waste acceptance schedule, this will initially preclude the need for additional at-reactor storage by nuclear utilities after January 31, 1998, and, ultimately, remove all eligible waste from at-reactor storage.

1/ The NWPA requires the Secretary to submit a triennial budget for the Nuclear Waste Fund. The discussion of specific activities presented in the Waste Fund Program gives estimates for FY 1986 and FY 1987. The estimates for the total Waste Fund Program are: FY 1986 - $525.4 million; FY 1987 - $528.6 million.

TABLE 1

FY 1985 CONGRESSIONAL BUDGET
NUCLEAR WASTE FUND
(Budget Authority In Thousands)

	FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
NUCLEAR WASTE FUND			
Repository Deployment			
o First Repository	$192,537	$246,560	$247,100
o Second Repository	12,322	16,270	28,700
Monitored Retrievable Storage	3,499	12,000	8,500
Program Management and Technical Support	7,175a/	40,091b/	40,069
Debt Service (Interest)	3,067	4,700	3,300
TOTAL	$218,600a/	$319,621b/	$327,669
Projected Receipts	(73,600)	(310,600)	(377,800)
Staffing FTE's	110	204	236

---

a/ Includes comparability adjustments of $1,275,000 for FTE's reassigned for other Departmental activities.

b/ Includes comparability adjustments of $946,000 for FTE's reassigned from other Departmental activities.

TABLE 2

FY 1985 CONGRESSIONAL BUDGET
ENERGY SUPPLY RESEARCH AND DEVELOPMENT ACTIVITIES
(Budget Authority In Thousands)

	FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
Civilian Radioactive Waste R&D			
Spent Fuel Storage R&D	6,389	5,000	13,200
Alternative Disposal Concepts	6,000	4,700b/	12,000
Generic Methods and Supporting Studies	17,875a/	1,600	2,174
Program Direction	130	130	266
TOTAL	$30,394	$11,430	$27,640

a/ Reflects adjustment of $125,000 transferred, to the Office of Energy Research for Small Business Innovative Research efforts in accordance with P.L. 97-219.

b/ Excludes $2,800,000 reprogramming from other DOE accounts accordance with Congressional directive in the Conference Report, H. Report 98-272, to P.L. 98-50.

Before discussing the details of the FY 1985 budget request, I would like to briefly give an overview of what we have accomplished since enactment of the Nuclear Waste Policy Act of 1982 and the mandated milestones that we have not met; the organization alignment for carrying out the responsibilities of Civilian Radioactive Waste Management; and the basic program strategy.

OVERVIEW

Accomplishments Since Enactment of the NWPA

Much has been accomplished in the 13 months since enactment of the NWPA on January 7, 1983. However, this also has been a period of organizing, reorienting and redirecting the Federal Government's nuclear waste management efforts under the new law.

The NWPA sets forth an unusually precise and complex schedule of tasks that must be accomplished and a set of procedures that must be followed. During the past 13 months, the NWPA required that the following major demanding tasks be accomplished:

- Within 90 days of enactment, identify states with one or more potentially acceptable repository sites and notify the Governors, the state legislatures, and the Tribal Councils of any affected Indian tribes in such states;

- Within 90 days of enactment, publish a joint Department of Energy/Nuclear Regulatory Commission (DOE/NRC) notice in the Federal Register that the United States is prepared to cooperate with and assist non-nuclear weapon states in at-reactor and away-from-reactor fuel storage, monitored retrievable spent fuel storage, geologic disposal of spent fuel, and the health, safety, and environmental regulation of such activities;

- Not later than 90 days after enactment, establish a one-time fee per kilogram of heavy metal in spent nuclear fuel or in solidified high-level radioactive waste existing prior to April 7, 1983;

- Not later than 180 days after enactment, establish fee collection and payment procedures;

- By June 30, 1983, enter into contracts with all owners and generators of spent nuclear fuel or high-level radioactive waste;

- Within 180 days of enactment, establish payment charges for Federal Interim Storage Services;

- Not later than 180 days after enactment, issue general guidelines for recommending repository sites;

- Not later than six months after enactment, submit to Congress a report describing the essential research and development needed to develop a proposal for a monitored retrievable storage facility;

- Not later than one year after enactment, select at least 1, but not more than 3, civilian nuclear power reactor sites to conduct a demonstration program, in cooperation with the private sector, for the dry storage of spent nuclear fuel;

- Within one year of enactment, submit a report to Congress with respect to alternative approaches to managing the construction and operation of all civilian radioactive waste management facilities, including the feasibility of establishing a private corporation;

- Annually prepare and submit to Congress a report on any plans for providing interim storage capacity;

- Submit an annual report to Congress on the activities and expenditures of the Office of Civilian Radioactive Waste Management;

- Not later than one year after enactment, transmit to Congress a report setting forth whether the Secretary plans to colocate a test and evaluation facility (TEF), if built, with a repository.

Of these 13 tasks, 10 have been completed on or before schedule. One, the TEF Report, will be several weeks late and only two have not been met:

(1) issuing general repository siting guidelines; and, (2) submitting a report to Congress on alternative approaches to managing the construction and operation of all civilian radioactive waste management facilities. The status of these two tasks is as follows:

(1) Siting Guidelines

As previously stated, the NWPA requires that DOE issue general guidelines for recommending repository sites within 180 days of enactment, and that these guidelines be developed in consultation with the Council on Environmental Quality, the U.S. Environmental Protection Agency, the U.S. Geological Survey and interested Governors. In addition, these siting guidelines are to be concurred in by the NRC. We have not as yet issued final guidelines.

In February 1983, DOE published draft guidelines. Public Hearings were held and written and oral comments were received. DOE met with representatives from affected and interested states to discuss the guidelines and to answer questions. More than 2,000 individual comments were received. An alternative guidelines document was issued to incorporate many of the comments and suggestions received. A second public comment period was provided. Due to this expanded consultation process, the 180-day deadline for issuing final guidelines passed.

After the close of the second comment period, which resulted in 900 additional comments, draft final guidelines were prepared and provided to the states. Following a plenary state consultation meeting and further revisions, the states were also given copies of a final internal review draft and invited to comment on important remaining issues. Final guidelines were subsequently forwarded to NRC for review and concurrence on November 22, 1983. NRC held a hearing on the guidelines January 11, 1984. Upon receipt of concurrence by NRC, DOE will issue final siting guidelines.

It is DOE's belief that the importance of full consultation with states and the need for public comment on the general guidelines to be used for recommending repository sites has warranted the delay in issuance.

(2) Report to Congress on Alternative Approaches to Managing

The NWPA requires the Secretary to undertake a study with respect to alternative approaches to managing the construction and operation of all civilian radioactive waste management facilities, including the feasibility of establishing a private corporation.

On December 16, 1983, the Secretary appointed an advisory panel to undertake this study. The panel is made up of thirteen representatives of State governments, Indian Tribes, private industry and the general public and has been charged with studying alternative means of financing as well as managing the problem. The panel's recommendations to the Secretary are expected to be completed by October 15, 1984 and the report will be submitted to Congress on or about December 31, 1984.

The organization within DOE which has been carrying out the waste management responsibilities since enactment of the NWPA is described below.

Organization

The NWPA called for the establishment of the Office of Civilian Radioactive Waste Management to be headed by a Director appointed by the President, by and with the advice and consent of the Senate. It is my understanding that the Secretary has recommended to the White House a candidate for Director.

Shortly after passage of the Act, however, the Secretary established a temporary project office to carry out the near-term requirements of the Act until the formal office could be activated. In October 1983, the Secretary formally approved and activated the permanent Office of Civilian Radioactive Waste Management (OCRWM).

The permanent organization has been divided into four major functional components. These four functional components closely align with those laid out in the Act. They are:

- Geologic repository activities;
- Storage and systems development activities;
- Management and management support functions; and
- Overall program direction and institutional relations.

The primary function of the Office of Geologic Repository Deployment is to site, design, construct, operate, and decommission the radioactive waste disposal facilities. It is also responsible for screening and characterizing potential geologic repository sites; recommending sites; conducting field tests including in-situ tests via exploratory shafts; developing waste emplacement packages; preparing documents to meet all regulatory, licensing, safety, environmental and quality assurance requirements; cooperating with State and Indian tribes; evaluating the need for and designing a test and evaluation facility; and managing the research and development of disposal technology for both repositories and alternative means of permanent disposal.

The Office of Storage and Systems Development manages the activities related to interim storage and any associated R&D efforts; monitored retrievable storage; waste packaging and handling; and transportation systems.

The Office of Management administers the Nuclear Waste Fund, the Civilian Radioactive Waste R&D Program, and, if activated, the Interim Storage Fund. It is also responsible for overall planning; budget preparation; financial management, management information, including personnel; and, data systems.

The Institutional Relations Staff has primary responsibility for developing and coordinating OCRWM's institutional and external relations.

Attachment 1 depicts the overall Headquarters organization structure and major responsibilities. Attachment 2 depicts the functional alignment.

Program Strategy

DOE is required to prepare a comprehensive Mission Plan to serve as a means of both planning the program and demonstrating its conformance to the requirements of the NWPA.

The Mission Plan will consist of two volumes. Volume I will be the plan for conducting the civilian radioactive waste management program, including discussion of the program's policy, strategy, plans and intended schedule. Volume II will include more detailed information to address the items specifically required by the Act, including an identification of the primary scientific, engineering and technical information; an evaluation of financial, political, legal or institutional problems that may impede implementation of the Act and plans to resolve such problems; and identification of the possible adverse economic and other impacts to the State or Indian tribe involved that may arise, from the development of a repository at a site.

An advanced copy of Volume I of the draft Mission Plan was sent in late December 1983 to the Nuclear Regulatory Commission and other Federal agencies, the Congress, State governments, affected Indian tribes, utilities and nuclear industries.

Volume II is currently being prepared. When completed, and as required by the Act, both Volumes of the draft Mission Plan will be released to interested parties, as well as to the general public, for review and comment by April 7, 1984.

When finalized in mid-1984, the Mission Plan will be submitted to Congress.

As set forth in the draft Mission Plan, DOE will pursue four major program goals:

1. Site, design, construct and operate the first mined geologic repository by January 31, 1998.
2. Design an engineered Monitored Retrievable Storage facility, on a schedule that will permit its timely construction, if authorized by Congress.
3. Assist utilities in providing adequate, safe at-reactor storage of spent fuel and stand ready to provide limited Federal Government storage to utilities if they are determined qualified by the Nuclear Regulatory Commission.
4. Manage the technical program and the funds collected for disposal and storage services, in an effective and efficient manner.

DOE plans to carry out this program with full adherence to the legislated institutional process, while developing sound technical data needed to support key milestones and decision points.

To accept high-level radioactive wastes for safe management, storage and permanent disposal beginning not later than January 31, 1998, a demanding set of technical, regulatory and institutional challenges will have to be met. With these challenges in mind, we have formulated the FY 1985 budget request that we are presenting to you today.

I would like to highlight some of the major elements of the FY 1985 program. The discussion is divided into two parts which coincides with the two separate budgets managed by the Office of Civilian Radioactive Waste Management: The Nuclear Waste Fund Program; and the Civilian Radioactive Waste Research and Development Program.

THE NUCLEAR WASTE FUND PROGRAM

Revenue Sources

The NWPA established the Nuclear Waste Fund to finance the waste disposal program. The Fund receives all the revenue the DOE collects from the nuclear utilities under the disposal services contract.

The main source of revenue for the Fund is the one mill per kilowatt hour fee charged for all electricity generated by civilian nuclear reactors beginning April 7, 1983. The NWPA provides for annual review and adjustment to assure that the fee is sufficient to recover all program costs.

A preliminary review and evaluation of this fee was undertaken during FY 1983 to determine if the one mill fee is sufficient to meet the full cost recovery mandate. The resulting report published in June 1983, estimates total system life cycle costs at nearly $20 billion in constant 1982 dollars.

Additional work on the fee adequacy was initiated in July 1983 to prepare for the next annual review to be published in July 1984. Based on the latest forecasts of the Energy Information Administration, revenue projections are declining. The near-term impact of the lower revenues could constrain the program. Therefore, the revenue projections contained in our FY 1985 budget now assume the 1 mill per kilowatt hour fee will be escalated to the rate of 4.7 percent in FY 1985 and 4.5 percent in FY 1987. DOE is still evaluating these estimates and will make its final recommendation in July 1984 when the annual Fee Adequacy Report is due to Congress.

Assuming that the 1 mill per kilowatt hour fee is escalated to match the inflation rate, revenue projections are as follows:

NUCLEAR WASTE FUND REVENUE PROJECTIONS
(In Thousands)

FY 1983	FY 1984	FY 1985	FY 1986	FY 1987
$73,600	$310,600	$377,800	$435,000	$504,300

High-level radioactive waste and spent fuel generated prior to April 7, 1983, is subject to a one-time fee per kilogram of heavy metal in such spent fuel or high-level waste. The fee must be equivalent to an average charge of one mill per kilowatt hour. The utilities have three options for paying this fee and must decide by June 1985 on the option they select. Until then, it is not possible to predict when these revenues will be available to the Fund. However, the one-time fee is estimated to be $2.3 billion now and will increase as interest is applied to the fee if the utilities choose to defer payment.

The Nuclear Waste Policy Act also requires the Department to evaluate the use of disposal capacity at one or more repositories for the disposal of high-level radioactive waste resulting from atomic energy defense activities. This study which is funded from the Defense appropriation is due to be completed in January 1985. If the Department decides to recommend disposal of the defense waste in a commercial repository, the Federal Government would pay for disposal of that waste in the repository.

Program activities funded by the Nuclear Waste Fund include: the geologic repository deployment programs; monitored retrievable storage; transportation; and program management and technical support. I would now like to highlight some of the major elements in those areas and in the FY 1985 budget request.

Repository Program

A. First Repository

The draft Mission Plan highlights a repository program divided into three phases. Phase 1 is Site Screening, Phase 2 is Site Characterization, and Phase 3 is Site Licensing and Construction. The current schedule for achieving major milestones within these three phases and associated with the first repository is as follows:

Phase 1

o Identification and Notification of Potentially Acceptable Sites (nine)	February 1983
o Issuance of Final Siting Guidelines	June 1984
o Issue Draft Environmental Assessments on nine sites	Summer 1984
o Issue Final Environmental Assessments on five or more sites	Fall 1984
o Nominate five or more sites as Suitable for Site Characterization and Recommend 3 Sites for Site Characterization	By January 1, 1985

Phase 2

o President Approve Sites for Characterization	March 1985
o Issue Site Characterization Plans for 3 Sites	March 1985
o Begin Exploratory Shaft Construction	March 1985
o Recommend First Repository to President	December 1990

Phase 3

o President Recommend Site to Congress	February 1991
o Submit Construction Application to NRC	February 1991
Receive Limited work Authorization	August 1991
Receive full authorization	February 1994
o Begin Repository Operation	January 1998

The FY 1985 budget request for activities associated with the first repository is $247.1 million. The FY 1986 estimated is $427.1 million; and the FY 1987 estimated is $403.2 million.

The FY 1985 activities included in the $247.1 million are as follows:

- Recommend three sites for site characterization for the first repository and begin detailed geologic, environmental and socio-economic studies and evaluations of those sites. Activities would include drilling and coring operations to better understand site stratigraphy and tectonics; comprehensive evaluation of site and regional geohydrology; other geotechnical analyses, such as seismicity, geochemistry and volcanism. ($58.2 million)

- Begin construction of and preparation for exploratory shafts at up to two of the three candidate sites and begin planning for performance of in-situ tests. ($56.2 million)

- Conduct site-specific engineering studies at the three recommended candidate sites consisting of evaluations of rock mechanics, shaft and tunnel excavation methods, equipment development, waste emplacement alternative methods and repository design studies. ($37.4 million)

- Conduct other engineering studies and analyses to determine the behavior of materials being considered for waste packages, develop test facilities for testing the performance of component materials and designs, and develop models and computer codes to ensure the engineered systems and the site will perform individually as well as collectively for overall repository performance. These studies will assist in the development of the necessary planning and licensing documents required by the NWPA and the Nuclear Regulatory Commission. ($85.7 million)

- Continue Federal/State assistance to States and Indian tribes so that they can participate in the repository plans and activities. These funds are provided to allow States and Indian tribes to study, determine, comment on and make recommendations on possible health, safety, environmental, social and economic impacts of a repository. ($9.6 million)

The FY 1986 and FY 1987 estimates of $427.1 million and $403.2 million, respectively, will support concurrent full site characterization efforts at all three recommended repository sites, shaft procurement and construction at those sites and enhanced site-specific waste package and repository engineering and design efforts.

B. Second Repository

Although construction of a second repository has not been authorized, the NWPA sets forth a schedule for siting a second repository. The activities for siting and designing a second repository include the same processes as for the first repository. The second repository program is being conducted so that the four-and-a-half year lag time between the recommendation of sites for site characterization for the first repository and the recommendation of sites for site characterization for the second repository will be preserved to the maximum extent possible.

The siting process for the second repository is presently in the regional characterizaion phase in which DOE is conducting studies in 17 states in media such as crystalline rock in the North Central, the Northeastern and the Southeastern parts of the United States.

The current schedule for achieving major milestones within the second repository program is as follows:

Phase 1

o Identification and Notification of Potentially Acceptable Sites	Summer 1985
o Issue Draft Environmental Assessments	Fall 1988
o Issue Final Environmental Assessments	Spring 1989
o Nominate and Recommend Sites for Site Characterization	Fall 1989

Phase 2

o **President Approve Sites for Characterization**	Fall 1989

Phase 3

o President Recommend Site to Congress	Summer/Fall 1995

The FY 1985 budget request for activities associated with the second repository is $28.7 million. The FY 1986 estimate is $50.6 million; and the FY 1987 estimate is $75.6 million.

The FY 1985 activities included in the $28.7 million are as follows:

- Continue development of a data base for studies in crystalline rock formation.
- Complete and issue draft crystalline rock area recommendation reports.
- Complete and issue draft crystalline rock area characterization plan.
- Identify potentially acceptable sites and notify States.
- Review of existing repository conceptual designs from the salt, basalt and tuff programs, along with review of repository designs for crystalline rock from the Swedish, Canadian and Swiss programs.

- Continue tests at th Stripa mine in Sweden and the Colorado School of Mines.

- Initiate testing at the Canadian Underground Research Laboratory and prepare plans and instrumentation for testing in the Climax facility in Nevada.

- Continue Federal/State assistance.

The FY 1986 and FY 1987 estimates of $50.6 million and $75.6 million, respectively, will support field investigations, including drilling of one or more boreholes, which will be completed in summer 1987.

To supplement repository site characterization and to resolve repository engineering and licensing issues identified through the licensing application review process, the NWPA authorizes DOE to build a Test and Evaluation Facility (TEF). The following is a discussion of the status of DOE's activities regarding a TEF.

Test and Evaluation Facility

DOE has evaluated the role and location of a TEF with respect to its potential benefits to the repository program. At this time, DOE believes that the acquisition of additional information, if needed in the repository program, can best be achieved by developing a collocated TEF. Our current plans are to make a decision in late 1987 on the need for a collocated TEF. No funds are requested in FY 1985.

The need for collocated TEF depends on the data needs of the repository program and how well the TEF will provide the needed data with respect to various considerations, including timing and cost. Additional information areas could be beneficial to the program. The pivotal issue is determining if these data are required for the successful design, construction, licensing and operation of the repository.

At this time, it is uncertain what role the additional data will play in the program and their degree of importance, relative to the data acquired during the site characterization phase. To a large extent, this uncertainty will diminish as the site characterization plans for the three candidate repository sites are prepared and submitted, reviewed by the NRC, and updated as more is learned about the sites and feedback from the NRC is incorporated into the program. By late 1987, according to the current repository schedule, five updates to the initial site characterization plans will have been prepared and issued, and initial test planning to aid in determining data needs will be well along. At that time, DOE will be in a better position to decide on the need for a collocated TEF.

I would like now to discuss our plans regarding the study of the need for and feasibility of an MRS.

Monitored Retrievable Storage

The near-term objective of the MRS program is to prepare and submit a proposal to Congress on or before June 1, 1985, for the construction of one or more MRS facilities. The FY 1985 budget request to support the MRS program is $8.5 million. The FY 1986 and FY 1987 estimates of $1.5 million, assume maintaining the MRS option without proceeding toward deployment.

In FY 1983, DOE prepared a report to Congress describing the research and development activities necessary to develop a MRS proposal. This report concluded that "no further research and development activities are considered necessary to develop a MRS proposal as required by the Nuclear Waste Policy Act of 1982."

The proposal due to Congress June 1, 1985, will be based on a detailed study of the need for and feasibility for one or more MRS facilities. The study will include detailed designs, specification, and cost estimates in sufficient detail to support Congressional consideration for auchorization of such facilities.

In October 1983, an Architect/Engineer was competitively selected to do the designs and plans necessary for the proposal. In the development of the MRS proposal, prime consideration will be given to safety and flexibility of the design concepts. The selected concepts have inherent safety features and are considered among the safest concepts considered. Since actual deployment of an MRS is dependent upon congressional authorization which will include, among other factors, the status and timing of the geologic repository program, flexibility is a key consideration in the MRS concept selection. The sealed storage cask and the open field drywell concept were selected. Both concepts are modular, capable of being designed and built with a small initial capacity but expanded as necessary with a minimum of lead time and cost penalty. Both concepts can also readily accommodate either spent fuel or solidified high level waste. These two design concepts will be developed as potential concepts for three potential sites.

In FY 1985, the design efforts will be completed, culminating in the presentation of the Proposal to the Congress. In addition, in FY 1985, a siting plan to be included in the proposal will be completed based on criteria and siting approach developed in FY 1984. Also, as required, an Environmental Assessment document will be completed and submitted to Congress with the MRS proposal along with a plan for integrating the MRS with the other authorized storage and disposal facilities.

The FY 1986 and FY 1987 estimates of $1.5 million each year will provide for proposal follow-up and updating of designs to respond to technology or requirements changes. Should the Congress decide to proceed with authorization of an MRS, activities in FY 1986 and beyond would include preparation of an Environmental Impact Statement, selection of an Architect/Engineer and Construction Management team, initiation of Title II design, site related activities, etc. However, additional funding would be required in FY 1986 and in FY 1987.

Program management and technical support is required to support the management of the Nuclear Waste Fund, the repository program and monitored retrievable storage programs as well as to integrate these programs. I would like now to briefly describe those requirements for FY 1985.

Program Management and Technical Support

The FY 1985 budget request for program management and technical support is $40.069 million. The FY 1986 estimate is $41.0 million and the FY 1987 estimate is $41.3 million.

The FY 1985 funding level of $40.069 million will support the following activities:

- Continue technical contractor support for conducting safety and design reviews; coordinating and developing licensing documentation; technical assistance support in program analysis and system engineering, cost trade-off studies, reviewing site characterization plans, reviewing environmental assessments; and reviewing design of shafts, surface facilities, and underground excavation for a repository and assisting DOE in coordinating the overall civilian radioactive waste management program. ($9.6 million)

- Develop standard material test methods; analyze repository transporation needs; and maintain inventory of spent fuel for future test programs and calculate fees. These activities include maintenance of the Engineer Maintenance Assembly and Disassembly (E-MAD) facility; development of standard materials characterization methods by the Material Characterization Center (MCC); transporation studies and systems integration analysis for the disposal program; and other supporting studies including fund management activities. ($14 million)

- Provide for a total of 236 Federal full-time equivalents (FTE's) for positions in the field and at Headquarters to manage funding, site investigation, technology development and institutional liaison required to obtain State, NRC and Presidential decisions for repository siting, MRS and supporting programs. ($16.469 million)

The FY 1986 and FY 1987 estimates of $41.0 million and $41.3 million, respectively, will provide for increased and continuing technical support in reviewing and updating the site characterization plans and for additional manpower to review site selection documents.

Debt Service

Debt Service in the budget request identifies the estimated interest expenses that the Nuclear Waste Fund will accrue. When the Nuclear Waste Fund was established in FY 1983, the NWPA required the Department to transfer all unexpended balances to the Fund which were previously appropriated under the Energy Supply Research and Development account for Fund activities. This transfer totaled $254 million. These funds are to be repaid with interest to the General Funds of the Treasury.

The FY 1985 Debt Service (Interest) requirements are $3.3 million. The FY 1986 estimates are $5.2 million; and the FY 1987 estimates are $7 million.

The Waste Fund is allowed to earn interest on funds in excess of outstanding Treasury debt. The current and expenditure projection indicate that liquidation of the debt will not occur prior to FY 1989. However, if the Department receives the lump sum payments of approximately $2.3 billion for spent fuel discharged prior to April 7, 1983, the Department might ask for supplemental budget authority to liquidate the debt sooner. Because the nuclear utilities have three payment options, two of which defer payments with interest, DOE cannot anticipate what monies will be received until the date upon which they must select the option, June 1985.

This concludes my discussion of the activities under the Nuclear Waste Fund Program; I would like to now to discuss the Civilian Radioactive Waste R&D Program which is comprised of generic research and cooperative agreement activities consistent with the NWPA but not eligible for funding through the Nuclear Waste Fund.

CIVILIAN RADIOACTIVE WASTE RESEARCH AND DEVELOPMENT PROGRAM

The NWPA requires the Secretary to budget for spent fuel storage R&D; alternative disposal concepts (subseabed) and generic repository research, development and demonstration activities under the Energy Supply R&D appropriation rather than funds collected from the utilities and deposited into the Nuclear Waste or Interim Storage Fund. DOE has established a new decision unit entitled Civilian Radioactive Waste R&D to accommodate both the existing R&D activities and those pertinent to generic research and waste management initiatitves under the NWPA. As previously, mentioned, the FY 1985 budget request for the Civilian Radioactive Waste R&D activities is $27.64 million.

I would like to briefly discuss the highlights of the activities which we plan to undertake in FY 1985.

Spent Fuel Storage R&D

Spent Fuel Storage Research and Development consists of R&D activities supportive of the NWPA which mandates the Secretary to take such actions as necessary to encourage and expedite the effective use of available storage and necessary additional storage at each civilian nuclear power reactor. The FY 1985 budget request to support these activities is $13.2 million.

FY 1985 activities include the following:

- Perform tests and analyses to determine the conditions under which spent fuel can be safely stored, and to determine the means to assure that the safe conditions are not exceeded in various applications.
- Continue a joint DOE/Tennessee Valley Authority cooperative demonstration of licensed storage of spent fuel in two dry storage casks.
- Continue a joint DOE/Nuclear Fuel Services cooperative demonstration to transport spent nuclear fuel in a dry storage cask, store and test fuel and reship later in the same cask. This activity will be initiated in FY 1984.

- **As required by Section 218 of the NWPA, participate with utilities and industry in the demonstration of new storage technologies to provide a data base for future NRC licensing actions.** Three utilities were competitively selected in October 1983 to participate in either dry storage technology or rod consolidation at-reactor demonstrations. The three utilities are Virginia Electric and Power Company (VEPCO), and Carolina Power and Light (CP&L) which will participate in dry storage technology demonstrations; and Northeast Utilities Services Company (NUSCO) which will participate in a rod consolidation demonstration. These cooperative demonstrations are currently being negotiated. Demonstrations will begin during FY 1984. These tests will be funded primarily by the private sector with DOE providing up to 25 percent of costs in the form of facilities, services and direct funding.

Alternative Disposal Concepts

The FY 1985 budget request for alternative disposal concepts is $12 million. The efforts conducted in this area are done so under the Subseabed Disposal Program which is an international program under the Nuclear Energy Agency in which the U.S., the European Economic Community and seven other countries participate.

Subseabed disposal is the only alternative to mined repositories currently being studied by DOE. The primary mission of the subseabed disposal program is to assess feasibility of isolating radioactive waste within the stable sedimentary formations of the deep ocean floor. The FY 1985 subseabed program request will allow the Department to complete the technical, environmental and institutional feasibility studies by 1990.

The Subseabed Disposal Program is intended to coordinate our efforts with several other Federal agencies and international groups and to proceed toward the goal of determining overall technical and environmental feasibility of the concept. DOE will utilize the many laboratories, equipment and ships which were developed and operated by other agencies and international communities.

In FY 1985, the Alternative Disposal Concepts program activities on the subseabed concepts will include cooperation with other nations' seabed disposal program through the Nuclear Energy Agency of the Organization for Economic and Cooperative Development (NEA/OECD). DOE is participating in the International Seabed Working Group on a cooperative basis. Efforts will include environmental science studies, physical oceanographic and biology studies, sediment mechanical response studies and waste emplacement studies.

One of the major efforts in FY 1985 will include continuing the thermal program which includes the In-Situ Heat Transfer Experiment (ISHTE) to test capability of the subseabed to accept waste containers. This experiment is a critical path item for the completion of the subseabed feasibility assessment. It will allow completion of the measurement of in-situ sediment strength and heat transfer capability of the sediment through deployment by an international team. These measurements will be taken by U.S. and the international devices attached to the sea bottom platform. Also, in-situ measurements of hole closure following penetration of the sea floor through an international team effort will provide information critical to assessment of the containment capability of the sea floor.

The FY 1985 request also provides for the completion of the seafloor mapping of the Atlantic references sites, testing of in-situ hole closure using free-fall penetrometers, completion of the construction of the ISHTE test platform in FY 1985 for deployment in FY 1986, deployment and recovery of an ISHTE mock-up platform, completion of biological and ocean models for migration of radionuclides, and acquisition of field data on the major parameters necessary for the prediction of the degree of containment provided by the subseabed and the ocean.

Generic Methods and Supporting Studies

The FY 1985 budget request for generic R&D and supporting studies is $2.174 million.

The Generic Methods and Supporting Studies activities include three main areas of effort: international program support, special technical reviews, and waste management system studies. The thrust of these efforts is to assure adequate international cooperation, provide an independent assessment of the technical adequacy of the program, and evaluate potential alternatives which could improve the cost, schedule or technical aspects of the Civilian Radioactive Waste Research and Development programs.

During FY 1985, the Department's international program efforts will support bilateral and multilateral international agreeements. Summary reports will be prepared on the various international programs of the numerous countries emphasizing the status and planning of international waste management activities. At present there are agreements governing information exchange with six countries; they are: Canada, the United Kingdom, the Federal Republic of Germany, Sweden, Belgium and Japan. Discussion with four additional countries are expected to result in additional agreements.

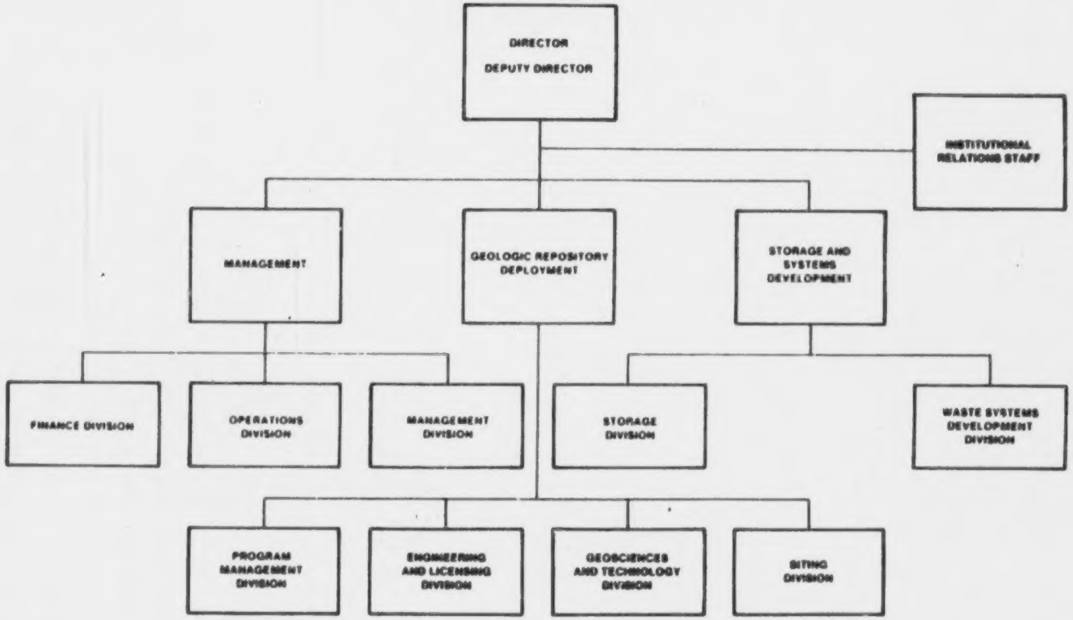
In FY 1983 and FY 1984, a joint DOE/NRC Notice was published stating the U.S. intent to cooperate and provide technical assistance to non-nuclear weapons states in the field of spent fuel storage and sisposla. We have received expressions of interest from Egypt, Korea, the Netherlands and Brazil. Informal expressions of interest have also been expressed by other countries.

During FY 1985, support of special technical reviews by the National Academy of Science (NAS) assisted by the Department of Transportation, and the Bureau of Mines will continue for their evaluations of rock mechanics and tunneling techniques in support of waste management activities. Independent assessments of technical and programmatic issues related to the integration and conduct of the Waste Management and Fuel cycle activities will continue. DOE will also support nuclear fellowship and university programs in the waste management area.

Program Direction

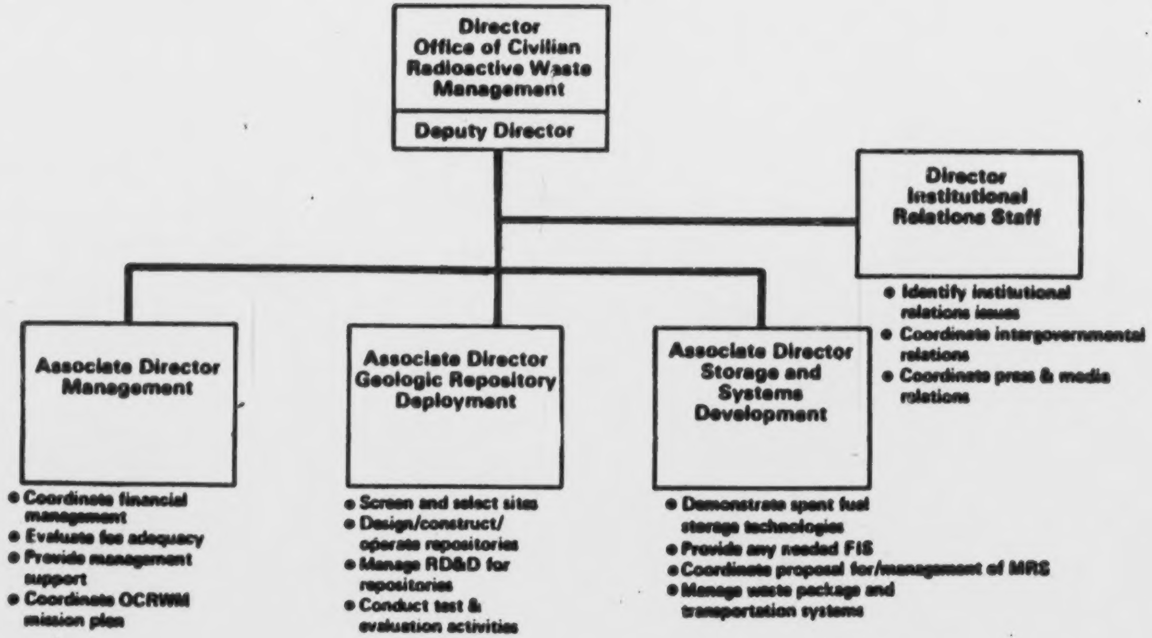
The FY 1985 budget request to fund five FTE's essential to manage the Civilian Radioactive Waste Research and Development programs is $266,000. The personnel required are located at DOE Headquarters and include administrative and technical talent who manage a broad range of activities, which include research, development, demonstration, industrial involvement, international and university programs. Their responsibilities include assessment of the technical progress, milestone progress, cost expenditures, guidance, overview and integration of all the contractor's activities, and initiation of appropriate actions to resolve problems in any of the R&D areas. This concludes my remarks in support of the FY 1985 Nuclear Waste Fund Program and the Civilian Radioactive Waste Research and Development Program. I shall be pleased to answer your questions at this time.

DOE
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT


DIRECTOR
DEPUTY DIRECTOR
INSTITUTIONAL RELATIONS STAFF
MANAGEMENT
GEOLOGIC REPOSITORY DEPLOYMENT
STORAGE AND SYSTEMS DEVELOPMENT
FINANCE DIVISION
OPERATIONS DIVISION
MANAGEMENT DIVISION
STORAGE DIVISION
WASTE SYSTEMS DEVELOPMENT DIVISION
PROGRAM MANAGEMENT DIVISION
ENGINEERING AND LICENSING DIVISION
GEOSCIENCES AND TECHNOLOGY DIVISION
SITING DIVISION

ATTACHMENT 1

Office of Civilian Radioactive Waste Management


Director
Office of Civilian
Radioactive Waste
Management
Deputy Director
Director
Institutional
Relations Staff
• Identify institutional relations issues
• Coordinate intergovernmental relations
• Coordinate press & media relations
Associate Director
Management
• Coordinate financial management
• Evaluate fee adequacy
• Provide management support
• Coordinate OCRWM mission plan
Associate Director
Geologic Repository
Deployment
• Screen and select sites
• Design/construct/ operate repositories
• Manage RD&D for repositories
• Conduct test & evaluation activities
Associate Director
Storage and
Systems
Development
• Demonstrate spent fuel storage technologies
• Provide any needed FIS
• Coordinate proposal for/management of MRS
• Manage waste package and transportation systems

ATTACHMENT 2

Mrs. **Lloyd.** Thank you very much, Mr. Lawrence, for your very fine and your very comprehensive overview.

I think our concern is that we will not be able to meet our commitments in 1998 with this sort of delay in the program. Do you really and truly think that we're going to be able to catch up?

Mr. **Lawrence.** I believe there are a number of options and ways which we could go about doing that, and I could go through that and they will be addressed in the mission plan. The mission plan right now indicates that, in order to meet the 1998 date, we would seek a limited work authorization from NRC at the time, or shortly after, sending over——

Mrs. **Lloyd.** We have made a commitment to the utilities?

Mr. **Lawrence.** That's right, and we take that seriously. Now, we feel that if a limited work authorization were granted in 1991, we could have a repository available in 1998 to begin accepting the waste from the utilities. I must caution you, however, NRC has not been favorably inclined to say that they would do that; and I think we have to build into our plans what happens if we cannot convince them that a limited work authorization is acceptable.

Mrs. **Lloyd.** Well, that could be the subject of further hearings in this committee as to how we could expedite this.

When will a decision be made on the test and evaluation facility and what conclusions have been made about this facility?

Mr. **Lawrence.** Well, we recognize we have a report due to this subcommittee concerning the test and evaluation facility. We have determined that the T&E facility would be best served if it were collocated with the repository, and that's the main thrust of our report which will be coming to you.

Therefore that, then, leads to a decision about placement and design; you have to tie that into your site selection process.

Mrs. **Lloyd.** Well, when does the construction begin on this, if you decide to proceed with it in this manner?

Mr. **Lawrence.** Well, if it were collocated with the repository, it could not start until 1991 at the earliest when that site is selected. However, if NRC licensing has to be obtained first, then it could not start until 1994 under our present schedule.

Mrs. **Lloyd.** Well, we didn't anticipate that NRC would license T&E facilities.

Mr. **Lawrence.** I recognize that.

Mrs. **Lloyd.** Is there a difference in programs?

Mr. **Lawrence.** There appears to be some difference of opinion between ourselves and the NRC on this. We do have to enter into a memorandum of understanding with NRC concerning the T&E, and we would hope to resolve that at that time.

Mrs. **Lloyd.** Well, we are pretty concerned in this committee that the Department is too lax in its commitment to meet this time schedule as set forth in the act, and we have heard many complaints about this, Mr. Lawrence, and we have heard that the program seems to be set up to encourage bureaucratic delays. Do you feel this is true? What are your comments along this line?

Mr. **Lawrence.** No, ma'am. We are committed to that date, in addition to—we feel our prime efforts have to be devoted toward having a repository available as of that date, but we do plan to have the monitored retrievable storage facility concept as a backup if authorized by Congress, to have it available in case of any extended delays of the repository. But in terms of bureaucratic delays, I think that—I don't believe that there have been any inordinate bureaucratic delays, but the delays that we have experienced to date have all dealt with dealing with the States, trying to reach agreement and understanding on things such as the guidelines.

Mrs. LLOYD. Well, one of the big problems with delays is that delays cost money.

Mr. LAWRENCE. That's right.

Mrs. LLOYD. Then the budget talks about escalating the 1-mill-per-kilowatt-hour charge. Now, is this escalation needed because the Department is delaying the program milestones that are set forth in the act?

Mr. LAWRENCE. No. We are not proposing, at this time, to increase the fee; the numbers that were in our budget proposal show an escalation if you wanted to insure that you did not have a negative cash flow through the 1987 period, as laid out in the act. But we are doing a study, which will be due to Congress in July, as to the adequacy of the 1 mill, and any recommendation. And right now, our efforts in the Department are directed at maintaining the program at a 1-mill-per-kilowatt-hour rate. One of the problems we have, however, is that that is a moving target with delays or deferrals of nuclear plants. The projection of revenues into the program over time also changes. I believe some numbers I was looking at indicated that, through 1987, our estimates between last year and this year with the slippages in nuclear plants that we've seen recently have resulted in $500 million less being available into the fund; so that is a problem which we will have. But our intent, and it's certainly our goal, is to lay out a program which will allow us to meet our key milestones and still maintain a 1-mill-per-kilowatt-hour fee, if possible.

Mrs. LLOYD. Well, I'm happy to hear that, and I hope that we can have continuing dialog before July on this matter, because it's not only of very grave concern to this committee but it's also a very important issue to this member, as well.

You know, when the Congress initially considered the level of fee to be charged to the utilities, we felt that the 1 mill per kilowatt hour was pretty generous and the funds that we were talking about would more than offset the costs to be incurred. Now, does DOE believe that its efforts to insure cost controls are adequate, and—what is being done by the Department to insure cost control?

Mr. LAWRENCE. We obviously have the existing Department cost control mechanisms as we go through the budget with review of the budget, with reviews of the programs and the plans. It's obviously very difficult for me to sit here and try to say that we're managing the program as best we can; that's always a difficult thing to do, but I would point out that last year, when our budget was submitted, obviously those numbers were not based upon a program that was built around the Nuclear Waste Policy Act, but the program in place prior to that time. After the passage of the act, our field requests for additional funds for the 1984 budget were on the order of $150 million over what we had asked for. We went back, worked with the projects, worked with the programs; that was later reduced to $33 million and later we felt that we could eliminate that request altogether. And in fact, at the end of the year we were able to transfer funds into fiscal year 1984 to reduce our requirements in the 1985 budget; this represents savings that we think we can realize in 1984 so that our 1985 request is on the order of—let's see—$29 million less than we had originally anticipated.

Given that, however, we still feel that we have to put on more controls on our costs and on our program to insure, not only to ourselves and to this committee, but to the utilities and, ultimately, to the ratepayer that we're managing the program in an efficient manner. Once the mission plan is completed and finalized so we know what our road map will look like, we then will go to specific project plans and program plans which will allow us to monitor costs, monitor schedules, and to have better control. Our goal is to have better control over the funding, over the program to make sure that the money is spent in an efficient manner. And we think that the record shows that we have made some cost-saving steps.

Mrs. LLOYD. Well, it does sound like an ambitious schedule.

Does the Department oppose utility auditing rights to insure cost control in this program?

Mr. LAWRENCE. We have received a letter from the utilities through EEI, the utility waste management group requesting a number of documents and working with them on our costs and we are responding favorably to that. We will provide that information and we look forward to working with them.

Mrs. LLOYD. I think that we will have additional questions for the record for you, and hope that you respond. And I do want to thank you and I don't want you to think that we're being overly harsh, but at the same time I hope that you realistically realize that this is an issue that is of very prime importance to this committee, that the bill originated in this committee; and it's not only a source of interest, it's a source of pride to us.

Thank you very much.

Mr. LAWRENCE. Thank you.

Mrs. LLOYD. Our next witness is Dr. Franklin E. Coffman. We welcome you, Dr. Coffman. And he will be accompanied by Tom Warner.

Is Mr. Warner with you?

Dr. COFFMAN. No, Madam Chairman, Tom Warner and Shelby Brewer apologize for their inability to come. Shelby wanted to come back today and visit with you on the extended burnup question, and I spent some time with him last night and hopefully I can answer most of your questions.

Mrs. LLOYD. Well, we're happy to have you. Please proceed with your testimony.

Dr. COFFMAN. Thank you very much, Madam Chairman.

STATEMENT OF DR. FRANKLIN E. COFFMAN, DIRECTOR, OFFICE OF TERMINAL WASTE DISPOSAL AND REMEDIAL ACTION, DEPARTMENT OF ENERGY

Dr. **Coffman**. I also have a statement which was included in Shelby Brewer's testimony to you yesterday, and that has been submitted for the record.

Mrs. **Lloyd**. Yes, that will be a part of the record of this hearing.

Dr. **Coffman**. So if I may, I would like to summarize for you what I think are today's objectives for the program and, most importantly, the achievements that we've accomplished in the past year and what we hope to do for you in fiscal 1985.

I also have two 6-minute videotapes showing the progress of the work at TMI and at West Valley, and so if you desire, we can show those.

Mrs. **Lloyd**. We certainly look forward to the presentations.

Dr. **Coffman**. OK. I would like to just go through the budget categories that I have to cover. The facilities under my purview and programs under my purview include the waste treatment program, the low-level waste program, the West Valley project, the TMI project, and the remedial action programs, including UMTRAP, uranium mill tailings, the formerly utilized sites programs, the surplus facilities programs, including the Shippingport power reactor decommissioning.

I will start briefly with the waste treatment program. This is a program that is conducted with PNL as the lead laboratory, and its basic R&D function is to provide the waste treatment technology base in the area of high-level, low-level, and transuranic wastes. It's centered around the construction of a ceramic melter which is being fabricated principally with U.S. moneys, although we will also have some German moneys as well. This facility will be operational by the end of fiscal year 1984, this coming October, and we will be making glass logs in fiscal 1985.

We were recently approached by the Germans, who are building a test and evaluation facility in the Asse salt mines, and they asked if we could use our ceramic melter facility to fabricate 20 to 30 borosilicate glass logs with full radioactivity content and full heat load, and we are about to sign—hopefully this week—an agreement wherein they would contribute $3 million into the waste treatment R&D program at PNL. We would fabricate 20 to 30 glass logs; we would ship those in 1986 and 1987 to Germany, completely at their cost, where they would install them in a test and evaluation facility at depth in the Asse salt mines in 1987 and 1988.

At the same time, this program is supporting the West Valley project, where we're using that technology to vitrify the waste there. We also vitrified some of the TMI abnormal high-level waste in this facility, so we've tried to weave together a very inexpensive program.

Mrs. **Lloyd**. Well, that's pretty good experience for us, isn't it?

Dr. **Coffman**. It certainly is. If you look at Japan or Germany, they're spending about $25 million per year in R&D in this area, and we are, by using existing facilities from other programs, we are running this program for you for about $6 million or $7 million, and it is the technology that is being adopted at West Valley and at the Defense waste treatment processing facility in Savannah River so I think you have a lot to be proud of in this program, considering the investment.

We also have the low-level waste activity, and in that program, in the past, we've played the role of facilitator to a large degree. We have tried to show what the waste source terms are, where they're going, what's the nature of the problems that regional compacts will face, and we've provided small amounts of money to individual States and to compacts to facilitate the compact effort. I understand that we have four before Congress and two more who are eligible to be submitted; we have a couple of States who are aggressively moving beyond that to attempt to site additional disposal facilities in either Texas or South Dakota. So there's been good movement in that program and, of course, the hardest part is yet to come; namely, picking a site in someone's State to dispose of the waste. But it's a good program, and another one you can be proud of.

As a part of that, when the High-Level Waste Policy Act was passed it gave the Department of Energy the authority to take certain special sites, such as are in Congressman Rahall's district. It also gave the Department the authority to take a low-level waste site after it is adequately decommissioned and the NRC certified that it is—that an adequate cemetery fee is available for it.

So this last year, since we met last, we have focused also on a no-cost-to-Government approach to removing the Sheffield, Ill., site from the books as a problem. We think we're very close with NRC and with U.S. Ecology; we are meeting with the State, attempting to remove that as an eyesore to the low-level waste compacting activities. And I'm optimistic within a year, hopefully by the time we're back next year, to be in agreement in some fashion with the State for the Department to take that at no cost to the Government.

We are also working with the State of New York and the State of Kentucky to find ways to get the three old sites off the books as continuing problems. Again, we're trying to do that principally with State resources, but as an adjunct to the facilitative role that we play.

I would like also to talk about the West Valley project. This is a facility that we took title to in February 1982; last October we got a cost estimate for that facility of $381 million in constant dollars. That has contingency and escalation in it, but it is not "as year" dollars. The "as year" dollar numbers come to $472 million. Westinghouse was picked as a contractor and, contrary to our TMI experience, they have come on board and we are chipping concrete and we've poured the pad for the ceramic melter; and by the time that I appear before you next year, we intend to have made a cold glass log in that facility.

Mrs. Lloyd. And we'll hold you to that next year.

Dr. Coffman. OK. I think it's important for you to recognize that while the Purex facility in Washington and the defense waste treatment facility in Savannah River are both planning to operate and go toward ceramic melter technology, by this October we will have a ceramic melter facility operating at PNL and by 1988 we will also have a ceramic melter making hot logs, vitrifying the waste at West Valley. So for the 1980's, these two programs which are under your jurisdiction, will be the only hot glass vitrification activities in the United States. So, again, I'm very proud of those, and we hope to show you progress with before and after pictures.

In the TMI area, it's a two-edged sword. It's a problem where we are very proud of DOE's and the Federal Government's role, and there are many things that I want to mention that we've accomplished; but we are stuck with the fact that every year the total budget for the cleanup is $20 million to $40 million under what is required for an aggressive cleanup program. Nonetheless, I would like to say that we have accomplished about 90 percent—

Mrs. LLOYD. Is that $30 million less funding than you really need to do what you want to do?

Dr. COFFMAN. Yes, for the total cleanup project. Now, in terms of our portion of it, the appropriations that we have—the authorizations——

Mrs. LLOYD. Well, I'm referring to the portion of it that comes under the jurisdiction of this committee.

Dr. COFFMAN. That part of it is quite adequate and quite satisfactory. As a matter of fact, we are slowing down a little bit the rate of expenditure of your funds because the balance—the industry contribution, the public utility contribution and the GPU contributions—have not been forthcoming. So we—the authorizations that we have asked have been more than adequate.

Mrs. LLOYD. Dr. Coffman, could you elaborate a little bit more in an additional memo to this committee? We'd like to have that as well.

Dr. COFFMAN. I'd be happy to provide a breakout of the formula.

Mrs. LLOYD. We do need that information.

Dr. COFFMAN. OK, I'd be happy to provide that.

[The information follows:]

It is the Department's practice in conducting the TMI—2 research and development program with General Public Utilities (GPU) Nuclear Corporation to provide specific work packages with defined mile-stones, rather than providing funding independent of technical progress. The pace of the Department's program matched the GPU cleanup effort through fiscal year 1983. However, recent delays in the GPU cleanup effort have resulted in corresponding delays in the Department's research and development program. As a result, we have proposed that $2 million of fiscal year 1984 TMI funds be reprogrammed to other Department activities. This reduces the Administration's commitment to TMI in 1984 from $37 million to $35 million. Assuming the President's budget is approved for fiscal year 1985, we will have spent $138 million. We would expect to request the remaining $21 million in fiscal year 1986 and fiscal year 1987.

Dr. COFFMAN. Nonetheless, I'd like to say that we've done 90 percent of what we have aimed to do with about 75 percent of the total program funding—by that, I mean the GPU funding—that's been available. You've seen a lot of pictures, a lot of news releases about things that have happened at TMI in terms of cleanup. I can't think of one that was not paid for, in whole or in part, by the authorizations from this committee. For example, we signed an agreement to take the abnormal waste on a reimbursable basis from GPU. Last August we made the last shipment; we have shipped 62 or 63 shipments of the abnormal waste, and have removed over 95 percent of all the loose radioactivity from TMI, and we now have gone through that phase and we're working to getting the crane fixed and the head removed and the fuel out.

Using your authorization, we built a camera system which I hope we can show you in a few minutes, to go in and examine what the nature of the core is. That was built by the Department of Energy as an R&D task and has already spun off in that GPU used that to inspect the adequacy of of TMI-1 for startup at their cost. So we are already getting commercial applications out of developments done under this program.

As I said, we shipped the EPICOR waste off; we shipped the submerged demineralizer waste off the island; we're working toward qualifying the polar crane this March, next month—that is a slippage because of the allegations that occurred last summer, and the management integrity issues which continue to rage between NRC and GPU. We do hope to get the head off of the reactor next fall, in fiscal 1984; we hope to get the plenum, which guides the control rods and sits under the reactor head; we hope to remove that during fiscal 1985 and, if we're successful with consolidating an adequate 1984 budget, and we're still working on it, we hope to start removing fuel in late 1986 at the latest. That represents a 6 month to a year slippage.

Mrs. LLOYD. What is the funding in this fiscal year for TMI?

Dr. COFFMAN. The current plan for calendar year 1984, for all practical purposes the same as the fiscal year, is about $80 million. They are desiring $95 million to $100 million. There are informal discussions going with EPRI and of course the utilities are negotiating their pledge——

Mrs. LLOYD. That's the total funding?

Dr. COFFMAN. That's the total; and in that $80 million total, our portion of that is about $14 million to $19 million. So of your $37 million, about $14 million to $19 million are R&D tasks which contribute to the cleanup formula.

Like I said, if we had a favorable IRS ruling—industry has $71 million in pledges, and when they reach $100 million and they start putting their money in—it could bring it up to $100 million. We are also pleased to announce that the Department of Energy has negotiated an agreement with the Japanese utilities to put $18 million and about $20 million worth of people into the TMI cleanup program. They advise us that after they get their 19 parties to sign this agreement in February of this year, the money will be forthcoming this May; so there will be $3 million there to augment your R&D program at TMI.

Mrs. LLOYD. That's very good, also.

Dr. COFFMAN. So there's a lot to hope for, but schedules have slipped; and if I may, I will move on to the remedial action program.

This program has four elements: Grand Junction, uranium mill tailings, formerly utilized sites, and surplus facilities. I would like to dispatch with Grand Junction.

That is a program that is funded 75/25 with the State of Colorado. The program has worked well; it's been run by the State, and by the end of fiscal 1985 we will have cleaned up, I think, 623 out of 626 residences and 1986 is the wrap-up year; and we hope to finish that program, essentially, in 1985. It's a small program, $2 million a year.

In the UMTRA program we also, I think, during the last year for the first time, had some things to be proud of. EPA put out their standards in March 1983 which started the 7-year clock ticking. Last year we conducted a budget scrubdown, and we scrubbed the TEC on that program down, without descoping, by over $100 million.

We did groundbreaking on the Canonsburg, Pa. site, which is a site of interest to Congressmen Walker and Austin Murphy and other people. We started groundbreaking on that; we are cleaning up vicinity properties this year, and we intend to have that site essentially finished at the end of fiscal 1985. It will be the bulk of our onsite work in 1984 and 1985.

We have also reached agreement with the State of Utah to relocate the mill tailings in south Salt Lake City to a remote site in Clive, Utah. This week we're negotiating as to who will clean it up and what will it cost, exactly. And we're optimistic that in fiscal 1984, the middle of the year, we will begin work on Salt Lake City. That will start work on your two highest priority sites and also the two sites which give you over 80 percent of the health risk in terms of radon emissions and public exposure.

So we have another one lined up in case we get into lawsuits—Shiprock, and we're moving dirt and cleaning up contaminated facilities.

In the formerly utilized site program, these are sites which go—in most cases—all the way back to the Manhattan engineering district. As you're aware, in the Senate appropriations bill last year, we were given four additional sites and $5 million of appropriation in fiscal 1984. In fiscal 1984 we intend to use those moneys to identify those vicinity properties, to clean as many of those vicinity properties up as we can, get agreement from the landowner for title to the site for interim storage, and move the contamination into an interim storage on the site. If the program is funded in 1985 adequately, we then would proceed with the NEPA documentation to try to wrap up most of the vicinity property work and do the engineering design on a disposal facility. We've told the States of New Jersey and New York that they must find a disposal facility if they want this material moved.

In the interests of time, I'm passing over—this is described pretty succinctly in the testimony, for I apologize for not being complete, but——

Mrs. **Lloyd.** Well, we will be reviewing the material in the record, so your overview is fine today.

Dr. **Coffman.** OK.

Mrs. **Lloyd.** Because we were late in starting, we would rather delay to you.

Dr. **Coffman.** OK, thank you.

In the surplus facilities area, these are facilities which are usually inside the DOE fence. They are facilities such as the Molten Salt Reactor, which is a standby facility in Oak Ridge; I don't think that belongs to us yet. But it is a level-of-effort program to work off facilities and, where we can, recondition them for future use.

That program has had, as its focus in 1984, the Niagara Falls storage site. This is a large facility which has off-site contamination on private lands, and we are trying, using the surplus facilities and the FUSRAP resources, to get the Niagara Falls storage site wrapped up by the end of fiscal 1985 and remove that as a problem.

If I could characterize this whole remedial action program, I see it as a bunch of dark spots on the page of nuclear energy; and I have a very simple approach, and that is to attempt to erase those dark spots one by one and brighten the picture for the nuclear program in the future. So we're taking a very simple, straight-forward approach; that is, clean the ones up that we can; be as economical as we can, and make sure that we don't have to come back and do it again.

A piece of that surplus facility, and the reason for the budget bump that you see, is the Shippingport decommissioning. The Department made a decision to go with prompt decommissioning. It's a 4-year project; it costs about $80 million, and we have the resources applied for in 1985 to begin Shippingport.

Now Shippingport has, for me, a very simple objective. It's a facility that's within 25 percent of the size of a commercial light water reactor, and we would like to go in, clean that facility up completely, and demonstrate that you can completely decommission a commercial-sized light water reactor for a very small fraction of the cost of constructing that reactor; and show people that commercial plants can, indeed, be cleaned up. Straightforwardly, quickly, 4 years, and cheaply, for $80 million.

Mrs. LLOYD. Well, will this cost and this effort be shared with industry? Does it serve as a demonstration of the costing methods?

Dr. COFFMAN. That's an intriguing idea.

Mrs. LLOYD. I think it's a great idea. [General laughter.]

Dr. COFFMAN. I think they would not volunteer because the reactor was a DOE demonstration reactor; it was a reactor that the Department of Energy used to transfer the submarine PWR technology into a commercial reactor design.

Mrs. LLOYD. But it's still technology that they can use?

Dr. COFFMAN. Yes. The R&D results are definitely of interest to them. But it was a DOE facility, so—it's intriguing and I think we will approach them for some participation. And I might add, our experience has been good on this. As I told you, I pointed out some $21 million of participation into your programs that have occurred just in the last year: $3 million from Germany and $18 million from Japan, and I'm going to Germany——

Mrs. LLOYD. I think those initiatives started with this committee as well, Dr. Coffman.

Dr. COFFMAN. Yes.

So, I am going to close—I would like to make one comment about West Valley. It's true that we do not have reprocessing, and we may not for several years; but I think the West Valley project will demonstrate a couple of things. Namely, that you can take liquid high-level waste from a commercial reprocessing plant; you can fabricate it into borosilicate glass logs suitable for the repository at a fraction of a mill per kilowatt, and that's a pretty profound thing to demonstrate.

We also plan to demonstrate that you can decontaminate a highly-contaminated, defunct commercial reprocessing plant for a small fraction of its total estimate costs. So we would like to debunk the idea that decontamination and decommissioning of commercial facilities, whether they are reprocessing plants or commercial reactors, is an expensive proposition.

So with that, I would take questions and, as I said, we have 2, 6-minute tapes which I think you might enjoy.

Mrs. LLOYD. Thank you very much. Let me proceed with my questioning at the present time.

On the subject of West Valley—this is another area of concern to this committee—is the Department planning any decontamination work at the reprocessing facility that is not unquestionably required for the solidification effort?

Dr. COFFMAN. Yes, I am familiar with that issue and it is a judgment call. What we are doing, at a minimum, is we are trying to avoid building any new facilities. We are trying to decontaminate facilities only to the extent of getting beneficial use and being able to run the ventilation system and put in the waste equipment and the storage equipment, as a minimum.

Now, I want to be very straightforward. The State of New York would like very much for us to completely decontaminate the facility.

Mrs. LLOYD. I'm sure they would.

Dr. COFFMAN. To the point that it could be released for unrestricted use. We do not plan to do that; for example, the CPC cell—it's the most highly contaminated, the main processing cell—we will only clean that down to the point that we can send occupational workers in to put equipment in it. So for the phase 1 part of the program, which is what is approved before this committee, we do not intend to completely decommission and decontaminate for unrestricted use. There is a phase 2 portion and I think it has to be visited jointly with this committee in the late eighties as to when we are done, do we share with the State the costs of decommissioning or do we turn title back to the State, leaving it residually contaminated somewhat as we found it, except for our activity?

Mrs. LLOYD. Well, we'll be looking into this situation further, Dr. Coffman, after we get through with getting our budget work completed.

Turning to commercial waste R&D programs, do you believe that the demonstration of hospital furnaces for low-level waste incineration was successful?

Dr. COFFMAN. I'm not sure I'm familiar with the specific issue that is there.

Mrs. LLOYD. Could one of your associates answer this?

Dr. COFFMAN. Let me ask Joe. Joe?

This is Joe Coleman, one of my division directors.

Mrs. LLOYD. Thank you. Would you identify yourself, Mr. Coleman?

Mr. COLEMAN. Yes. I'm Joseph Coleman; I'm working in the Department of Energy, in the nuclear energy side and I have under my responsibility the low-level waste management program.

We have conducted a joint project with the University of Maryland in regard to incineration of hospital-type wastes that we feel has been extremely successful in showing that these wastes can be incinerated, essentially, at the hospital using a commercially available incinerator with some slight modifications. This incinerator has been installed at the University of Maryland Hospital in downtown Baltimore and has been extremely successful in reducing the amount of waste which they have, in the past, generated and had to be transported to disposal sites, to virtually zero. Very, very small amounts of radioactivity are involved but very large volumes of combustible waste. We think it's been very highly successful.

Mrs. LLOYD. Have you made any effort to really encourage other hospitals to use this technology? I think we asked you to send letters to the hospitals, and so forth.

Mr. COLEMAN. Yes, we have. We've had a great deal of inquiries from a large number of hospitals. In particular, for example, New York City, and we have assured that presentation of this work has occurred around the country at a variety of meetings and through personal consultation by the project manager for this.

Mrs. LLOYD. Very fine. Thank you very much.

How much funding is requested for the development of a universal spent fuel container? There's one for storage, one that could be used for transportation, storage, and disposal. Would this be coordinated with the work at EMAD?

Dr. COFFMAN. Madam Chairman, it's my——

Mrs. LLOYD. I think Mr. Lawrence wants to answer.

Dr. COFFMAN. I have to say that it's my unfortunate experience that I lost that function, and my deputy——

Mrs. LLOYD. As I started to say, I think that's Mr. Lawrence's responsibility, so I'll let him or his associates answer it.

Dr. COFFMAN. I might say, Madam Chairman, that his expertise comes from training with me for all those years.

Mrs. LLOYD. I can see that there's a distinct likeness and both of you have done your homework today, so I'd like to compliment both of you.

Mr. LAWRENCE. Thank you, Madam Chairman.

As far as a universal waste package is concerned, we had $2 million set aside in the 1985 budget for activities in this area. I can't be more specific than that at this time because we are going out on the street at this point in time with a request for proposals from industry and utilities as to waste packaging systems that could be put into place to make the whole system more efficient, safer, cheaper. And it will be working with utilities and with activities—such as, TVA has already started, we've been in communication with them——

Mrs. LLOYD. I was going to ask you about the input that TVA had made in this area.

Mr. LAWRENCE. I had discussions with representatives from TVA last year about this. We're very high on it, and what they're doing on their own; and we're going to coordinate our activities. We're also aware that the Edison Electric Institute, working with the utilities, also has some activities in this area. We want to coordinate that.

At this point in time, however, we don't want to rush and say, "Here's the solution" until all of the possibilities and all of the ramifications can be looked at, and that's why this broad participation—utilities, industry, and the government—we think, is appropriate.

Mrs. LLOYD. Well, my concern is actually the timing. Will we have it available for the repository?

Mr. LAWRENCE. There is ample time for a 1998 operation of the repository.

This also should fit in very well with the transportation responsibilities that the Department has under the Nuclear Waste Policy Act, although we intend to use—as directed by the act—private industry for this; we think that's appropriate. It's clear to us that the existing cask fleet, which was designed for 6 month cooled fuel, probably will be inefficient even though it can be safely used in the near term. Eventually, when you have a large-scale operation like that repository, we would like to see a new fleet available that would fit together a total package system from the reactor to the repository and any intermediate steps in between, such as MRS's or a reprocessing plant. We want that to all fit together, and we're taking steps to do that.

Mrs. LLOYD. Thank you very much.

One final question on the LWR extended burnup program. As you know, this committee is very interested in this program. How much funding do you think would be required, Dr. Coffman, to continue this program to achieve the program goals that we originally anticipated?

Is that too broad a question?

Dr. COFFMAN. Madam Chairman, I would like to submit a detailed answer for the record, but I can provide some comments.

[The information follows:]

The Department has not estimated annual costs for continuation of this program toward its original goals, since the policy is to close it out, as described in the Administration's budget submission, and to leave further development and commercialization to the private sector.

Dr. COFFMAN. As you know, there were some other contracts which were not placed; and if those were not placed and the program was brought to an orderly close, the plan and what the Department submitted was to use $3 million approximately of prior-year budget authority to bring the plan to an orderly close.

Mrs. LLOYD. Well, it's my opinion that around $10 million would sort of keep the program going.

Dr. COFFMAN. I think that is correct. My understanding from staff is that if the program were proceeded with, with initiation of all the new contracts which had been entertained and discussed, that it might take as much as $10 million per year for 3 or 4 years.

Mrs. LLOYD. Well, is the Department planning to terminate this effort before our program goals are achieved?

Dr. COFFMAN. Yes, ma'am. The budget that was submitted—what I am advised is that the Exxon Corp. and the Westinghouse Electric Co., which are fabricators of fuel, have developed in parallel to this program an extended burnup commercial development activity, and that they are now in the position to sell warranted high burnup fuel assemblies so that part of the objective of this program was to transfer the technology to industry. And as I understand, it was the feeling of the Department that this had been pursued to the point that commercial development would fill in any gaps or potholes that might remain in the R&D road to full utilization of burnup. Clearly, there was no disagreement that this was one of the most valuable programs in terms of extending the burnup and minimizing the volumes of that waste; and so we're together on the philosophy. But I think the feeling was—and it is judgmental—that with the industry picking up the cudgel, that we could step back at this point with the completion of the existing contracts.

Mrs. LLOYD. Yes, but a 50,000-megawatt base per metric ton was the goal which would be achieved under the terminated program.

Dr. COFFMAN. Yes. And I think, as I understand, we are up about 30,000 or 31,000 metric tons in terms of commercial sales at this time—30,000 megawatts, rather.

Mrs. LLOYD. Well, what contracts would be terminated?

Dr. COFFMAN. It's my understanding—and I would like, again, to qualify my mistakes with a statement to the record—is that none were terminated, but there were some that were envisioned to be initiated that were not picked up upon, but that the programs would be brought to a close. Now, I may have misspoken; again, I apologize. I spent time with Shelby last night and I did not manage this program, so——

Mrs. LLOYD. Well, you might want to supply it for the record. We were concerned of what burnup would be achieved under the terminated program. If you'd like to supply us more information for the record.

[The information follows:]

No contracts have been cancelled and none will be cancelled during the current fiscal year. For fiscal 1985, three conracts are scheduled for cancellation and all other contracts are scheduled for normal completion. All of the contracts to be cancelled are with utilities acting as prime contractors, each working with a fuel supplier as a subcontractor, as follows: (1) Arkansas Power and Light/Babcock and Wilcox. (2) Arkansas Power and Light/Combustion Engineering. (3) Duke Power/Babcock and Wilcox.

Dr. COFFMAN. I would appreciate it if I may. Again, Shelby extends his apologies for not coming today.

[The prepared statement of Mr. Brewer follows:]

PREPARED STATEMENT OF SHELBY T. BREWER, ASSISTANT SECRETARY FOR NUCLEAR ENERGY, DEPARTMENT OF ENERGY

Madam Chairman and Members of the Subcommittee, I am pleased to be here today to discuss the Department of Energy budget for nuclear fission energy programs. Our Energy Supply research and development funding request for FY 1985 is $590.4 million in budget authority, as compared to the $663.4 million appropriated in FY 1984. The requested funds are distributed among the program elements as indicated in the following table.

[In millions of dollars]

	Fiscal year—	
	1984	1985
Program Element:		
Converter reactor systems	92.7	83.5
Breeder reactor systems	[1] 423.2	308.1
Advanced nuclear systems	34.2	33.5
Remedial actions	99.0	152.0
Nuclear waste technology	14.3	13.3

	Fiscal year—	
	1984	1985
Subtotal energy supply R&D	663.4	590.4
Uranium enrichment	[2] 2,193.8	1,675.3
Uranium enrichment revenues	−2,105.0	−1,675.3
Subtotal (net)	88.8	0
Total	752.2	590.4

[1] Includes $40 million transferred from uranium enrichment program for Clinch River breeder reactor termination.
[2] Includes $130 million of funding; excludes $40 million transferred for Clinch River breeder reactor termination.

Before describing these program elements in detail, I will comment briefly on a number of the external factors that have influenced preparation of our fiscal year 1985 budget.

The past year has been a complex mixture of successes and disappointments for nuclear energy. We have a President who strongly supports nuclear power and recognizes it as an essential element of a balanced energy supply for the future. In 1983 three new nuclear powerplants achieved commercial operation status, raising the annual output of nuclear generated electricity to almost 300 billion kilowatt-hours, or about 13 percent of our total electrical generation. Nuclear power continues to provide us with safe, clean energy. Its economics are on a par with coal, and substantially more favorable than oil or gas. In spite of this impressive performance, nuclear power is not considered an attractive investment by the electric utility industry. Six plants wre cancelled in 1983—and hour more were either cancelled or indefinitely delayed in January of this year. In addition, no new plants have been ordered since 1978. The fact that this disturbing situation is the result of complex and interrelated economic, regulatory, and institutional problems, rather than any deficiency in the technology, is of little practical consequence. While we are seeing a daily improvement in economic indicators that gives us some hope of renewed investment, as yet that hope has not materialized. To dwell on our defeats, however, is counterproductive. We must now turn to new and alternative strategies of ensuring future nuclear vitality. With this challenge in mind, we have formulated the budget request that we are presenting to you today.

Our proposed programs are supportive of the President's nuclear policies and are entirely consistent with the Department's National Energy Policy Plan (NEPP-IV) sent to Congress last Fall. Our goal of ensuring that nuclear power remains a viable option for a balanced and diverse energy resource base contributes to the national goal of fostering an adequate supply of energy at reasonable costs. Important elements of this balanced system are new advanced technologies to provide adequate energy supplies well into the future. Our programs support the policy of minimizing Federal control and involvement in energy markets. Accordingly, all nuclear research and development will be conducted with an eye to transferring the technology to the private sector for demonstration and deployment as soon as is feasible.

We interpret our role as one of extending the nuclear technological horizon in order to create private sector opportunities for commercializing and marketing those concepts that best meet their needs. In addition, we must continue to fulfill the Federal responsibility for maintaining public health and safety and environmental quality in regard to all nuclear-related activities under our jurisdiction.

Madam Chairman, I would now like to highlight some of the major elements of our fiscal year 1985 nuclear program.

CONVERTER REACTORS

In structuring our Converter Reactor Program in fiscal year 1985 we have been keenly aware of the institutional problems that confront the current generation of commercial nuclear power—the light water reactor. The utilities are not committing capital for the construction of any large powerplants, be they nuclear or coal. Unless, and until the fundamental problems that result in unacceptable business risk for the utilities are resolved, there will be few, if any, orders for new, large powerplants of any kind. The consequence of this is higher than necessary electricity costs. For industries where electricity costs make up a substantial portion of their business expenses, such as the aluminum industry, this will result in a serious deterioration of their competitive position in the world market and/or the necessity to expand outside the United States with the attendant loss of jobs.

In some areas, utilities are turning to imports of Canadian nuclear electricity as a near-term expedient to reduce their supply costs. Unfortunately, these solutions reflect our inability as a Nation to solve the fundamental problems confronting the electric utility and nuclear industries today. The commercial nuclear power industry in the United States has taken over a quarter of a century and hundreds of billions of dollars to develop. The Nation must consider seriously the effects of the continued decline and ultimate demise of this industry.

We have analyzed carefully what steps the Federal Government could and should take to effect solutions that would renew confidence in the nuclear option. A priority emphasis will be on continued efforts to encourage passage of nuclear licensing reform legislation. The outdated system currently in use was established over 25 years ago. A more predictable process is badly needed to ensure efficient licensing and regulation of the plants already in operation or under construction. It is also a prerequisite to a renewed utility interest in nuclear investment.

On March 18, 1983, DOE sent to Congress its legislative proposal for improving the regulatory and licensing process for nuclear powerplants with the following three major objectives: (1) To provide for continued improvement in the safety of nuclear powerplants; (2) to improve the effectiveness of public participation; and (3) to provide a more stable and predictable licensing process.

The NRC also submitted a proposal for licensing and regulatory reform. It is important to note that the Administration's proposals are not an attempt to resolve the debate over the need for nuclear power or its desirability when compared with other energy sources. Nuclear licensing reform is a necessary but not sufficient condition for new nuclear powerplant orders. The proper role of nuclear power in the Nation's energy future should be decided by the free market system, but it cannot receive proper consideration if we continue with an inefficient and outmoded Federal regulatory process.

In addition to our effort to contribute to the resolution of problems confronting the nuclear industry, the Department will also be evaluating alternative, advanced designing concepts. There is need to develop the technology for reactors that have less complicated safety systems and better economics, thereby increasing both public and utility confidence. We will also be evaluating the potential of small High Temperature Gas Reactors for unique domestic and international markets. Where appropriate, we will conduct collaborative programs with Japan and the Federal Republic of Germany. This is one of a number of areas in which we will be pursuing increased international cooperation in technology development.

The Converter Reactor Program also supports the cleanup at TMI. As you know, DOE has limited its effort to performing generic research and development that can contribute substantially to our knowledge both of accident recovery and accident prevention. We believe important technical progress is being made, but activity is impeded by a shortfall of required funds. The nuclear industry, through the Edison Electric Institute, pledged support for the cleanup with a target of $150 million. One hundred million dollars is required before funds can be transferred to General Public Utilities, the TMI owner. To date, only $80 million has been pledged but a recent favorable Internal Revenue Service ruling, which makes pledges tax deductible, is expected to generate additional funds. Although the DOE commitment to TMI cleanup remains firm, it now appears that our fiscal year 1984 and 1985 expenditures will be less than planned due to slower than expected progress by the other parties involved in the effort.

BREEDER REACTOR SYSTEMS

Our fiscal year 1985 request for Breeder Reactor Systems reflects the major restructuring that has taken place in the breeder program. While our overall goal remains the same—to develop the technology for introduction of a marketable breeder reactor by the private sector early in the next century—our strategy has changed. Last year our activities were project-oriented around Clinch River construction and operation. With the termination of Clinch River, our program focus has shifted to resolving those technical issues that stand in the way of commercialization by industry. We understand breeder technology; the United States still has the greatest technological base for breeders in the world, and we know it will work. The challenge now is to make it commercially viable. That can be done only if the cost of the product is brought in line with the cost of its competition and if it can be made attractive (i.e., safe and reliable) to both the customer and the public. And this challenge must be faced in light of new realities regarding Federal support for energy development. The Government simply will not finance future breeder demonstration powerplants. While the Federal Government will continue to be needed to provide certain institutional and financial support, large capital outlays are not practical or appropriate in the budgetary and political environment we face. Nor are they likely to be practical for some time to come.

The challenge then is to develop a breeder concept that can be built by the private sector on an economic basis, with the Federal Government playing a strong but limited role. In fact, during the past year, we have encouraged and supported industry to develop advanced reactor designs aimed at meeting sound economic, reliability, and safety criteria.

The Clinch River Project has produced valuable experience in the areas of design, component testing, and licensing. This information will be retained for use in the restructured base technology program. NRC's Atomic Safety and Licensing Board recently issued a memorandum of findings which resolved all issues in the CRBR Construction Permit hearings in favor of the Applicants. This decision, which would have been sufficient to authorize the issuance of a construction permit, confirms the technical merit of the CRBR Project. It also provides firm conclusions regarding the safety and environmental acceptability of breeder reactors and provides a benchmark for future breeder licensing effort. Clinch River Project close out activities are proceeding smoothly. An appropriation transfer of $40 million has been made from the Uranium Enrichment Program as an interim measure to fund CRBRP termination requirements. No new appropriations are expected to be requested in fiscal year 1985.

The LMFBR research and development program in fiscal year 1985 will be directed toward improving the technology for power conversion systems, components, instrumentation, and materials technology to the point where cost reduction and reliability potentials are realized. Continued operation of the breeder test facility complex at the Hanford Engineering Development Laboratory (HEDL) and the Energy Technology Engineering Center (ETEC) will provide the experience base and test capability for this effort.

The program will also assess advanced breeder concepts that offer the potential of improved economic and safety. These studies will include investigation of smaller-scale breeders, standardized designs, and reactors manufactured as a complete package or as modules in central fabrication facilities. They will be conducted with input from industry, the ultimate customer for breeders. Moreover, cooperative research with, and technology transfer to, the private sector will constitute an important element of development activity.

Another priority element of our program will be a substantial increase in international cooperative effort. We see significant benefits to be gained from the division of workload and the pooling of resources. We also anticipate that joint effort will encourage uniform or compatible safety standards, physical security measures, and safeguards.

In fiscal year 1985, we will continue development of the breeder fuel cycle technology as well as confirmation of fuel breeding in a light water reactor using the uranium-233 fuel cycle. Our breeder fuel cycle program, however, will be conducted at a substantially lower level of effort. The lower funding recognizes the reduced requirements in both pace and extent for breeder fuel cycle technology development as a result of Clinch River termination. It is my personal belief that this is a period of reassessment and the circumstances will evolve that signal the need for more aggressive development of the breeder fuel cycle.

ADVANCED NUCLEAR SYSTEMS

Another important area of Departmental activity is the research and development of advanced nuclear systems in support of U.S. military and civilian space missions and other special applications. Work is divided into two major subprograms. The first is the Special Isotopic Power Sources Program. In fiscal year 1985, flight systems development, production, and safety support will be conducted for isotopic power generators to be used in the Galileo and International Solar Polar spacecraft to be launched by NASA in 1986. Design efforts for an advanced modular generator to be used in space missions and for other special applications will be continued. A second program element is the Space Nuclear Reactor Program, which is a cooperative effort of the DOD, NASA, and DOE to examine several reactor concepts for potential use in future space missions.

WASTE TECHNOLOGY

As you know, Madam Chairman, under the requirements of the Nuclear Waste Policy Act of 1982, the activities associated with the siting, construction, and operation of a national repository system for high-level nuclear waste were assigned to the newly established Office of Civilian Radioactive Waste Management. Prior to that, in 1980, legislation was enacted starting that the responsibility for disposal of low-level nuclear waste rests with the States. My role in nuclear waste management is to develop waste treatment technologies for the long-term management, storage, and disposal of civilian radioactive waste, be it low-level, high-level, or transuranic. In fiscal year 1985, one of our activities will be to conduct safety and reliability tests on the ceramic melter system which is to be used to solidify high-level waste. We will also continue to provide technical assistance to the States in their efforts to establish (either individually or by regional compacts) facilities for low-level waste disposal. In this regard, I am pleased to report that progress in forming compacts has been encouraging. To date, four compacts await Congressional approval and two more have been approved by the required number of States (four) in each region to permit submission to Congress.

REMEDIAL ACTIONS

Another important Federal responsibility in the management of nuclear wastes is our program for remedial actions at certain contaminated facilities and sites. This program is divided into four major subprograms. (1) The Formerly Utilized Site Remedial Action Program (FUSRAP) covers former nuclear processing sites that require stabilitzation or removal of contaminated material. DOE currently has authority for conducting remedical action at 19 sites. In fiscal year 1985, remedial action will be completed at the Niagara Falls Storage Site in New York and work will continue at other sites for which DOE has authority. (2) The Uranium Mill Tailings Remedial Action Program (UMTRAP) is directed toward the cleanup of 24 inactive uranium mill tailings disposal sites and several thousand associated vicinity properties. In fiscal year 1985, cleanup will be completed at the Canonsbury, Pennsylvania, site and about one-third of the necessary work at the Salt Lake City, Utah, site and two-thirds at the Shiprock, New Mexico, site will be compieted; (3) A third program covers our participation in a Federal/State cooperative effort to remove uranium mill tailings used for construction purposes in Grand Junction, Colorado. By the end of fiscal year 1985, we will have completed remedial actions at 623 of the 626 structures requiring attention. (4) The Surplus facilities Program provides for the safe management and disposition of contaminated DOE civilian program facilities (currently grouped into about 55 projects) that are no longer in use. In fiscal year 1985, dismantlement of the Shippingport Atomic Power Station will be initiated, which will demostrate the safe and economical cleanup of a commerical power reactor.

Yet another waste management activity for which we have responsibility is the demonstration of high-level waste solidification [illegible] the Western New York Nuclear Center near West Valley. In fiscal year 1985, the West Valley Program will focus on vitrification testing, engineering, and procurement of waste solidifiction support systems and decontamination and decommissioning of the facility.

URANIUM ENRICHMENT

I have saved discussion of one of the Department's business enterprises—the Uranium Enrichment Program—for last. The problems I reported to you a year ago—a worldwide excess of enriched uranium, increasing competition from foreign enrichment suppliers, and the emergence of the secondary market—are still with us. Today the U.S. share of the global enrichment market has dropped significantly from the monopoly it held 10 years ago. Customers, understandably, are attracted to suppliers that can offer lower prices and more flexible contract terms enrichment services. Decreased demand, DOE's outmode business practices and the drastic change in currency exchange rates no longer allow us to be a competitive supplier.

Over the past year we have analyzed the situation carefully, considered alternative options, and developed a strategy that we believe will significantly improve the U.S. market position. Our most pressing needs are to stabilize our market share, provide an orderly work-off of excess inventories, and stem the tide of customers who are going elsewhere for their enriched uranium. Consequently, the first element of our strategy was to offer a new contract with terms sufficiently attractive to interest potential customers and to retain our present customers. This step was taken on January 18 with the issuance of the Utility Services contract. The new contract offers several competitive features including a reduced price with a long-term price ceiling, the ability to pruchase a portion of requirements from foreign suppliers or the secondary market, and ordering and delivery provisions that are substantially more flexible.

The second element of our strategy is to plan and conduct the activities in all areas of the uranium enrichment enterprise in a more efficient and cost effective manner. With regard to existing production capacity, we are making vigorous attempts to obtain relief from the TVA demand charges for power and to introduce more effective cost control measures into our gaseous diffusion operations. As market data are obtained from customer response to the new contract, we can adjust our program scope and outlays in proportion to our revenues.

The market response to our new contract will also determine future investment in new capacity and in research and development. An important element of our long range strategy is to replace the gaseous diffusion operations with technologies that are more energy efficient and, ultimately, more cost effective. As you know, we are currently building a Gas Centrifuge Enrichment Plant (GCEP) at Portsmouth, Ohio. Our plan is to proceed in fiscal year 1985 with construction of GCEP buildings 1 and 2 and procurement of Set III centrifuges. No funds are committed to any additional buildings at this time.

We are developing advanced gas centrifuge (Set V) and the Atomic Vapor Laser Isotope Separation technologies. In the near term we plan to continue R&D on both. In fiscal year 1985, we plan to select one of these advanced technologies for further development.

Success in our new enrichment strategy will affect a number of important national considerations. It will enable our domestic utilities to have a reliable indigenous supply of fuel. It will insure that our defense requirement are met. And by meeting the needs of foreign nations it will further our nonproliferation objectives.

In summary, Madam Chairman, the nuclear programs we are describing today differ markedly from those of the past. We have acknowledged the realities of the marketplace and have introduced modern principles of good business into our programs. In recognition of the constraints of the current national fiscal policy we have set strict priorities for sharply focused activity. And, we have a clearer delineation of government/industry responsibilities. One thing that has not chanaged, however, it our belief in a strong nuclear option and our commitment to strive for its realization. We look forward to working with this and other committees of Congress in achieving this objective.

I would not like to describe in some deatil the Department's nuclear programs.

CONVERTER REACTOR SYSTEMS

The fiscal year 1985 budget request for Converter Reactor Systems is $83.5 million, a decrease of $9.2 million from the fiscal year 1984 appropriation. The distribution of funds is as follows:

[In millions of dollars]

	Fiscal year—	
	1984	1985
Light water reactor system	19.5	16.0
High temperature reactors	30.0	34.6
Advanced reactor systems	5.0	0.0
Three Mile Island activities	37.0	32.2
Program direction	1.2	0.7
Total	92.7	83.5

The overall goals of the Converter Reactor Systems Program are: (1) to improve the economic and safe use of nuclear reactors; (2) to contribute to the resolution of the nuclear industry's regulatory, financial, and institutional problems; and (3) to fulfill the Federal Government's research and development commitment associated with General Public Utilities' cleanup of Three Mile Island (TMI).

Light water reactor systems

The Advanced Reactor Evaluations element of our program will focus on safety in improved advanced converter reactors. While the current LWR industry has an outstanding safety record, there are improvements that may be made to any technology. The basic question of how changes in the current size and design of commercial converter reactors could improve safety (both real and perceived), and better meet the utility needs, will be addressed by this program.

The Department will continue to fulfill its role of reviewing and reporting to Congress on the national research and development programs conducted by both private sector and government organizations, as required under Public Law 96-567.

We will also continue participation in the Loss-of-Fluid Test (LOFT) Program, and internationally funded activity under the auspices of the Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development (OECD). This consortium selected a test program to be carried out over a three year period beginning in fiscal year 1983. During that year, three thermal-hydraulic tests were successfully performed within budget and ahead of schedule. In fiscal year 1984, the final three thermal-hydraulic tests will be completed and preparations will be made for two fission-product release and transport tests. These fission product tests, to be performed in fiscal year 1985, will provide important data relevant to the magnitude of the readioactive source-term, which is a singificant input to the technical basis underlying many nuclear licensing and regulatory requirements. By early fiscal year 1987, all analysis should be completed and the LOFT reactor deactivated and decontaminated.

The original total LOFT program cost estimate was $93.5 million. Of this, NRC provided $25 million in fiscal year 1983, DOE is providing $45 million in increments of $15 million in fiscal year 1984, 1985, and 1986, the Electric Power Research Institute is contributing $1.5 million, and foreign countries are expected to contribute $22 million.

High temperature reactors

Following completion in fiscal year 1984 of activities related to the design of a proposed large high temperature gas-cooled reactor (HTGR), efforts in fiscal year 1985 will be refocused to evaluate the potential of small HTGRs for unique domestic and international markets. In addition, the development of the technology base needed for HTGR electric and process heat applications will be supported. These activities and objectives are consistent with the current policy of support for long lead time, high technology advanced concepts that cannot be fully supported by the private sector.

The primary thrust of this program will be to evaluate and develop the potential of small gas reactors for multiple applications. Technical and economic design assessments will be performed to guide the base technology development activities and the selection of a reference small reactor concept. The technical approach is to utilize the inherent lower power density of small HTGRs to minimize the need for engineered safety features. The evaluation and development of the HTGR concept will be closely coordinated with appropriate user groups to assure evolving marketplace compatibility. Alternative market, business, and financial strategies will be developed by the users consistent with their needs and requirements in order to guide the evaluation of the small HTGR and the configuration of the HTGR which best meets the needs of the market.

The HTGR program will also emphasize the advancement of the technology base needed to support the development of small, gas-cooled reactor systems with less complex safety systems. Additionally, technology activities will be performed to address many of the technical design safety issues that have been identified from the operational experience gained at Fort St. Vrain, from changes in nuclear regulation, and from changes in user (utility) requirements.

Advanced reactor systems

In fiscal year 1984, efforts have continued on irradiation testing of candidate replacement low enriched uranium (LEU) fuel systems and fabrication development to qualify commercial sources of these alternative fuels. In fiscal year 1985, funding for this program is not being requested by the Department of Energy; however, the Arms Control and Disarmament Agency has requested funding to support this activity in fiscal year 1985.

Three Mile Island Activities

The Three Mile Island (TMI) program is budgeted under the Converter Reactor program but is managed under the Office of Terminal Waste Disposal and Remedial Action, and is discussed under that section of this statement.

BREEDER REACTOR SYSTEMS

The Breeder Reactor Systems budget request for fiscal year 1985 is $308.1 million, a decrease of $115.1 million from the fiscal year 1984 appropriation. Distribution of the funds is as follows:

[In millions of dollars]

	Fiscal year—	
	1984	1985
Clinch River breeder reactor plant (termination)	[1] 40.0	0
Liquid metal fast breeder reactor	300.8	261.6
Nuclear fuel cycle	35.4	11.9
Water cooled breeder	35.5	26.3
Program direction	11.5	8.3
Total	423.2	308.1

[1] An Appropriation transfer of $40.0 million has been made from uranium enrichment as an emergency interim measure to fund immediate CRBRP termination requirements.

Liquid metal fast breeder reactor program

The Liquid Metal Fast Breeder Reactor (LMFBR) program has been restructured to focus on resolving those technology issues that are key to improved breeder economics and predictable, safe performance. The revised program will be fully consistent with our Natioal energy research and development policy in that there will be no new Federally funded demonstration projects. The responsibility for demonstration of breeder reactor technology, including definition of program scope, timing, funding arrangements, and management, resides with the private sector. The Federal program for fiscal year 1985 complements industry efforts by emphasizing:

Technology research and development necessary for a breeder system that has less complicated safety systems, is reliable, is competitive with alternatives, and meets the market needs of utilities; development of advanced plant concepts; major, substantial international collaboration; and development of LMFBR fuel cycle technology.

A major effort will be directed toward advancing the technology for power conversion systems, components, instrumentation, and materials technology, as well as for the related fuel supply system, to the point where cost reduction and reliability potentials are realized. Testing of breeder systems, fuels, components, instruments, and materials takes place at the Hanford Engineering Development Laboratory (HEDL), the Energy Technology Engineering Center (ETEC), and the Argonne National Laboratory (ANL).

Recent studies indicate that advanced breeder concepts can be economically competitive with alternatives (e.g., LWR's and coal plants) and deployed with relatively short lead times in sizes matched to various grid requirements. The feasibility of these advanced breder concepts will be assessed with input from the user industry, the ultimate customer for breeders. Explicit attention will be given to the potential advantages of small reactors of standardized design that are capable of being replicated in total (or by module) in central fabrication facilities. Small-sized fuel cycle facilities also have attractive economies to match plant sizes. Cooperative research with, and technology tranfer to, the private sector will constitute an important element of the reoriented breeder program.

A major thrust of the fiscal year 1985 program will be the emphasis on international collaboration in breeder technology to reduce U.S. program costs and to retain the U.S. role in international nuclear forums. The experience gained in design, component testing, licensing, and analysis from the CRBRP project as well as our advanced breeder knowledge acquired from the operation of the Fast Flux Test Facility (FFTF) and the base program will be valuable in establishing exchange agreements with other nations.

A smaller-scale effort, the Water-Cooled Breeder program, is devoted to providing breeding can be achieved in a light water reactor using the uranium-233/thorium fuel system. Efforts in fiscal year 1985 will continue the defueling activities and core evaluation of the light water breeder core from the Shippingport Atomic Power Station.

Clinch River breeder reactor plant project

There were no funds appropriated to continue the Clinch River Project in fiscal year 1984. Therefore, on November 10, 1983, the parties involved—the Department of Energy (DOE), Tennessee Valley Authority (TVA), Commonwealth Edison, Project Management Corporation (PMC), and Breeder Reactor Corporation (BCR)—agreed to terminate the project, effective November 14, 1983. The agreement was formalized on December 19, 1983.

Termination activities began in early fiscal eyar 1984, and are planned for completion in early fiscal year 1985. These include the termination and/or relocation of project personnel; termination of contracts and subcontracts; site redress work; settlement of terminated contracts and subcontracts; documentation of certain completed work; completion of selected computer verification efforts that were approaching completion when the project was terminated; arrangement for retention and appropriate availability of scientific and technical information generated under the project; storage, maintenance, relocation of CRBRP components, equipment, materials, etc., for use within the LMFBR program and other Government programs, as appropriate; and disposition of inventories not of value to the LMFBR program.

Large scale prototype breeder

The Government sponsored design efforts on a Large Scale Prototype Breeder (LSPB) plant will be phased out in an orderly manner during FY 1984. The program has been a joint effort of the U.S. Government and private industry to develop a large scale prototypical breeder demonstration plant. The plant was to have been the logical follow-on to the Clinch River Project as a full-scale demonstration plant. The LSPB design will be maintained as a frame of reference for benchmarking advanced concepts developed under the base program.

LMFBR base program

The mission of the LMFBR base program is to develop the requisite technology to the point where the private sector is able to construct and operate safe, reliable liquid metal fast breeder reactor plants for suppling electricity to the grid. This includes studies of the technical features applicable to future private sector initiatives. The program has been reoriented to place primary emphasis on designing less complicated safety systems and achieving economic competitiveness in future advanced concepts. It is to this end that the breeder technology and test facilities efforts discussed in the following paragraphs are directed.

Concepts and requirements development.—An effort will be initiated to identify plant concepts that could be developed by industry for use in the marketplace and to assess unique market needs that can be satisfied by the breeder technology program.

During fiscal year 1985, development efforts on the advanced concept studies will be conducted by contractors selected during fiscal year 1984 as part of a competitive procurement process. This effort will include development of plant requirements and safety criteria; safety analyses; licensing assessments; seismic evaluation; constructability assessment; identification of R&D requirements; and analysis of cost and schedule potential. Market analysis will be conducted to assure proper program and concept development. The studies will utilize to the maximum extent possible previously developed technology and information gained under the current international collaborations, including the DOE/Japanese MONJU agreement. R&D requirements will be constantly coordinated with other parts of the base program.

Beginning in fiscal year 1984 and during fiscal year 1985, an information exchange will be conducted with the Nuclear Regulatory Commission (NRC) aimed at developing licensing criteria for future advanced LMFBR's. Key LMFBR issues will be identified and used as a basis for improving the licensability of LMFBR's and contributing to an efficient licensing process.

Power conversion technology.—It is essential that major cost reduction and reliability potentials are realized in order to justify investor and public acceptance to build and operate economically competitive liquid metal reactors. The Power Conversion Technology Program focuses on these potentials and encompasses the power conversion systems and the components necessary to convert heat to electricity. Standardized plants and more cost effective methods for achieving quality assurance and two concepts of special interest for accomplishing the reduced costs and reliability goals.

The research and development to improve the performance predictability and reliability of power conversion components includes flow induced vibration analysis, flow distribution testing and analysis, mixing and stratification testing and analysis, subcomponent development and testing, fabrication process development, inspection development, and procedure development. Efforts are underway to develop data on materials properties, including fabrication and environmental effects. Lese Documentation of these data in handbook form will serve as an authoritative source for use in the design and licensing processes. The program also includes the development of a new ferritic alloy which offers significant economic and engineering advantages over current reference structural alloys.

Significant accomplishments for fiscal year 1984 include: successful completion of sodium testing of the 35,000 GPM pump which disclosed needed modifications that would not otherwise have been discovered; successful completion of sodium testing of the hockey stick steam generator in both the recirculation and once-through modes; and successful completion of water testing of the 85,000 GPM two stage primary pump preparatory to shipping all pump system parts to ETEC by the end of 1984.

Specific accomplishments planned for fiscal year 1985 include: continue preparation for sodium testing of the helical coil model steam generator; develop a 14,000 GPM electromagnetic primary sodium pump for modular reactor applications; and initiate balance-of-plant cost reduction, simplification, and standarization studies. Fabrication of the 70 MWt double-wall tube steam generator will continue, with delivery in fiscal year 1986. Development of this component has the long-term potential for eliminating the intermediate sodium system and avoiding the need for a sodium water reaction product separation system.

Fuel performance and supply.—The Fuel Performance and Supply program's objectives include proving the performance of fuel, blanket and absorber core components under prototypic operating conditions and demonstrating safe, reliable, and licensable core systems. Specific objectives include extending the lifetime of core components to a minimum of 3 years; automating fuel fabrication to achieve competitive fabrication costs; improving safeguards and reducing personnel exposure; and transferring developed technology to industry.

The development of carbide and metal fuels for advanced and smaller sized plants will proceed because of the potential advantages in smaller control requirements, smaller sizes, and lower fuel cycle costs that these fuel systems offer. International participation in the Core Systems and Materials Program will continue to reduce program costs while maximizing technological benefits.

In the Fuel Supply area, activities will continue toward completing the Secure Automated Fabrication (SAF) line. Procurement of equipment and its installation in the Fuels and Materials Engineering Facility (FMEF) will continue. Upon its completion and operation in the late 1980's, the SAF line will demonstrate breeder fuel fabrication technology that can be deployed commercially by industry. Activities for fuel assembly capability in the FMEF will be initiated in fiscal year 1985.

Nuclear systems technology.—The disciplines of safety, physics, structures, thermal hydraulics, and reactor core design are integrated into a single, cohesive unit in the Nuclear Systems Technology program. The program will focus on experimental verification, in existing DOE facilities, of the feasibility of advanced reactor concepts of varied design, size, and fuel type that exhibit self-terminating capability under failure conditions. All functions needed to assure nuclear safety under abnormal conditions are integrated into the nuclear systems. Demonstration of inherently safe nuclear systems operations will reduce the requirements for supporting auxiliary equipment whose purpose is to control otherwise dangerous conditions. Such support equipment substantially increases the complexity of design. These studies will enable the development of a reliable advanced technology that is competitive and compatible with user needs and capability.

Varied fuel types (metal, oxide, carbide) and fuel pin sizes will be evaluated, as well as the effects of varied core designs on voiding, temperature, and reactivity coefficients. Features supporting inherently safe operation will be developed, reflecting the redirection in the safety program which places more emphasis on the existing safety features of breeders and less on breeding ratios and other plant parameters.

Work will continue in support of upgrading the TREAT reactor to provide the principal in-reactor safety phenomena testing capability. Also, a program of operational safety experiments on integrated systems will be conducted at the EBR-11 reactor facility.

Test facilities.—The test facilities effort consists of operating and maintaining facilities at the Hanford Engineering Development Laboratory (HEDL), the Energy Technology Engineering Center (ETEC), and the Argonne National Laboratory (ANL) to conduct LMFBR program test requirements. In addition, the Los Alamos National Laboratory (LANL) conducts nuclear related studies and assessments in support of the program.

HEDL facilities

The Hanford Engineering Development Laboratory (HEDL), which is operated by Westinghouse Hanford Company in Richland, Washington, plays a key role in breeder reactor development and testing activities. The major test facility at HEDL is the Fast Flux Test Facility (FFTF) which provides a test bed for demonstrating and evaluating the performance of breeder reactor fuel assemblies and partial core loadings at reference conditions. Efforts will focus on operation of the FFTF and the installation of the Secure Automated Fabrication line equipment.

Facilities operated at the HEDL site include:

The Fast Flux Test Facility (FFTF), a 400 MWt liquid metal (sodium), cooled fast-neutron-flux loop type reactor designed specifically for irradiation testing of nuclear reactor fuels and materials for fast breeder reactors.

The performance of the FFTF during 1983 and 1984 is particularly noteworthy; three full cycles of operation were completed and preparation for a fourth is now underway; the ractor was operated for a nominal 100 days during each cycle and, in the third cycle, experienced 55 days continuous full power operation without interruption. The performance of the fuel subsystem exceeded its design goal burnup of 85,000 megawatt days per tonne during the third cycle without failures.

The Fuel Storage Facility, located adjacent to the FFTF, is used to store and remove decay heat from irradiation FFTF fuel and reactor experiments.

ETEC

The Energy Technology Engineering Center (ETEC), which is located 40 miles northwest of Los Angeles and is operated by Rockwell International, is the breeder program's nonnuclear component testing center. ETEC has several large on-site nonnuclear sodium testing facilities with the unique capability to test fast breeder reactor components under all operating conditions. Some smaller ETEC facilities will accomplish testing on selected on selected small reactor plant components, instrumentation and subsystems. Efforts will continue toward realizing innovative methods for economical long term steam generator testing.

ANL Facilities

The Argonne National Laboratory (ANL) efforts are primarily accomplished at the ANL-West (ANL-W) site at the Idaho National Engineering Laboratory. These activities include plant and component operating experience in addition to specific testing efforts in support of fuel performance and nuclear systems technology. Development of innovative methods to achieve economical long term testing of key components such as pumps, steam generators, and inherent safety features is a continuous effort in parallel with testing activities.

Facilities that are operated at the ANL-West site include: the Experimental Breeder Reactor-II (EBR-II), the Hot Fuel Examination Facility (HFEF), the Zero Power Plutonium Reactor (ZPPR), the TREAT (transient test) Reactor.

LANL

The Los Alamos National Laboratory (LANL) efforts are primarily general program and nuclear studies and assessments, and nuclear training activity.

Initiatives in support of cost-effective operations are being implemented throughout the test facilities complex. Cost and schedule controls ensure economic and efficient use of the test facilities; consolidation of testing and demonstration activities is continuously under review. Facilities surplus to base program needs will be phased out.

Nuclear Fuel Cycle

The fuel cycle activities include development of advanced technology for reprocessing of irradiated fuels from nuclear power reactors with emphasis on the more stringent requirements associated with reprocessing breeder reactor fuel. These include higher thermal and radiation burdens, higher fissile content, sodium contamination, and more complex fuel assembly structures. The technical program is focused on development of technology that will provide smaller-scale facilities for equivalent throughput, reduced radiation exposure to workers, increased environmental protection, increased reliability, enhanced safeguards, and reduced costs.

In fiscal year 1984, design, fabrication, and testing of advanced smaller size, higher throughput equipment in the Integrated Equipment Test (IET) facility at Oak Ridge will continue to evaluate performance and remote maintenance concepts. Specific items to be tested include fuel disassembly and shear systems, a continuous rotary dissolver, centrifugal contractors for solvent extraction, and an advanced servomanipulator needed for remote operations and maintenance.

In fiscal year 1985, remotely operable and maintainable reprocessing equipment and systems will be developed and some integrated cold testing in the Integrated Equipment Test Facility will be conducted. Laboratory and hot cell experiments on low sheet development will continue at a reduced level. Efforts in fiscal year 1985 will also include providing supporting analysis and evaluation for the light water breeder reactor proof-of-breeding demonstration, and evaluation of methods and cask designs for handling and shipping irradiated breeder fuel.

Water cooled breeder

The Water Cooled Breeder program's mission is to develop technology for significantly improving the efficiency of nuclear fuel resource utilization by light water reactors used for electrical power generation. The objective is to accomplish the following: prove that breeding can be achieved in a light water nuclear reactor using the uranium-233/thorium fuel system; confirm a practical way to use thorium (a plentiful source of fuel for which there has been no major energy-related use); show the feasibility of installing prebreeder and breeder cores of the light water breeder reactor type in existing and future pressurized water reactor plants using current types of plant components and systems; and make the technology developed under the program available to industry.

A light water breeder core was installed in the Shippingport Atomic Power Station in 1977. On October 1, 1982, the Shippingport Station ceased power operations; end-of-life testing was performed and defueling of the light water breeder reactor core was begun.

Core removal operations are scheduled to be completed by the end of fiscal year 1984. Major activities in fiscal year 1985 will include: completing documentation of core removal operations; preparation for long term storage of expended fuel; and shipping of spare and physics fuel rods to storage.

Core evaluation work in fiscal year 1985 will include: disassembling light water breeder core fuel modules for examination and storage; providing facilities and equipment for light water breeder fuel module examination and assay; preparing fuel rods for nondestructive assay; performing of proof-of-breeding work; analyzing effects of extended core operation on core materials; and continuing thermal and hydraulic analysis of light water breeder reactor components.

ADVANCED NUCLEAR SYSTEMS

The Advanced Nuclear Systems budget request for fiscal year 1985 is $33.5 million, a decrease of $0.6 million from the fiscal year 1984 appropriation. Distribution of the funds is as follows:

[In millions of dollars]

	Fiscal year—	
	1984	1985
Special isotopic power sources	27.7	28.0
Advanced systems evaluation (space nuclear reactor)	5.0	4.5
Program direction	1.4	1.0
Total	34.1	33.5

The goal of the Advanced Nuclear Systems program is to develop and deliver specialized nuclear power sources for U.S. military and civilian space missions and other special applications. Activity is conducted within two program elements: the Special Isotopic Power Sources program and the Space Nuclear Reactor program. the latter is a tri-agency cooperative endeavor of DOD, NASA, and DOE.

The Advanced Nuclear Systems Program supports civilian and military space applications through the development of a range of nuclear power system options. A number of developed nuclear isotopic power sources are used by the Department of Defense and the National Aeronautics and Space Administration; operating data from these systems are being reviewed. For example, Pioneer 10 launched in 1972 and Pioneer 11 launched in 1973, continue to transmit telemetry data which indicate that the space isotope power supplies are operating as designed. In addition, the DOD Lincoln Experimental Satellites 8/9 (in orbit since 1976) and the NASA voyager 1 and 2 spacecraft (launched in 1977) continue to obtain their total spacecraft power needs from their onboard isotope generator.

The current generation of Radioisotope Thermoelectric Generators (RTGs) under development will deploy the General Purpose Heat Source (GPHS) for the NASA Galileo and International Solar Polar Missions planned to be shuttled launched in 1986. Each GPHS RTG weighs 123 pounds and produces about 285 electrical watts.

Special isotopic power sources

The fiscal year 1985 isotope power development program has three major activities. First, the readiness and shipment of the GPHS RTG flight units to be used in the silicon germanium generator for the NASA Galileo and the International Solar Polar Missions. The second effort is the development of a new modular RTG concept that offers the potential for a more advanced, much lighter generator, i.e., high specific power to weight ratio, for future space missions. During fiscal year 1985, ground demonstration system (GDS) fabrication and assembly will be accomplished. The third activity involves RTG development for special military applications. In fiscal year 1985 emphasis will be on the GDS fabrication, completion of final design definition, and the safety evaluation of the RTG.

Advanced systems evaluation (space nuclear reactor)

The Space Reactor Development Program and the Space Power Advanced Reactor Program were consolidated to form the Space Nuclear Reactor (SP-100) program to support a Memorandum of Agreement which was signed on February 11, 1983, by the Defense Advanced Research Projects Agency (DOD), the Office of Aeronautics and space Technology (NASA), and the Office of Nuclear Energy (DOE). The agreement establishes the relative responsibilities of the three agencies during the conceptual development phase of the program. In fiscal year 1984, several reactor system concepts are being examined to determine which concept would enhance or enable future civil and military space missions. Long lead efforts in technology development and related tasks began in 1983 and will continue through 1985. A key decision is planned during fiscal year 1985 on whether to proceed with a ground engineering prototype demonstration. If a decision is made to proceed to a prototype, substantial increases in funding will be necessary in fiscal year 1986 and beyond for the ground engineering test, for associated facilities improvements at a DOE laboratory or contractor location, and for the transition of the program into more detailed design and development activities.

The current multi-agency agreement expires at about the end of fiscal year 1985. A new agreement will be necessary if a decision is made to proceed to the SP-100 Ground Engineering test Phase (fiscal years 1986-1989). Upon selection of a specific system for the final development, the management structure will be changed to a more traditional line structure with separate activities and clearly defined interfaces for each agency. DOE will be responsible for developing the nuclear subsystem during this phase.

During fiscal year 1985, several reactor development system contractors will be funded in order to develop reactor conceptual designs for space systems applications. Conceptual designs will be developed and a baseline, backup, and growth design will be completed. System and nuclear safety program activities are to be continued in preparation for potential ground engineering systems tests scheduled for fiscal year 1986.

REMEDIAL ACTION PROGRAM

The fiscal year 1985 budget request for the Remedial Action Program is $152.0 million, an increase of $53.0 million over the fiscal year 1984 appropriation. The distribution of funds among the program elements is as follows:

[In millions of dollars]

	Fiscal year—	
	1984	1985
Formerly utilized sites	17.0	16.0
Grand junction	1.5	1.5
Uranium mill tailings	27.9	54.0
Surplus facilities	15.5	30.0

	Fiscal year—	
	1984	1985
West valley	36.0	49.4
Protram direction	1.1	1.1
Total	99.0	152.0

The objective of the Remedial Action program is to treat or stabilize radioactive wastes and perform required decontamination and decommissioning at contaminated DOE and at legislatively authorized non-government facilities and sites. The major activities are: (1) the Formerly Utilized Sites Remedial Action Program (FUSRAP); (2) remedial action at Grand Junction, Colorado (Public Law 92-314, as amended); (3) the Uranium Mill Tailings Remedial Action Program (UMTRAP) for inactive uranium mill tailings sites (Public Law 95-604); (4) management of certain radioactively contaminated Department facilities declared surplus and resulting principally from civilian nuclear energy programs; and (5) demonstration of the solidification of high-level radioactive wastes at West Valley for final disposal (Public Law 96-368).

Formerly utilized sites remedial action program

The Formerly Utilized Sites Remedial Action Program (FUSRAP) provides for remedial actions at former nuclear processing facilities, most privately owned, which became radioactively contaminated from Manhattan Engineer District or Atomic Energy Commission activities and which have not been decontaminated sufficiently to meet current health effects guidelines. To remedy the situation, the contamination will be either stabilized in-place, with restrictions placed on site use, or the contamination will be removed and disposed of at another location. Authority derived from the Atomic Energy Act of 1954, as amended, currently exists for conducting remedial actions at 15 sites. This authority is based on our review of the involvement of agency predecessors in activities at these sites. Review of other sites involved in past activities of the agency's predecessors is continuing and may result in the addition of sites to the program. Congress added four new sites and $5.0 million in the fiscal year 1984 Energy and Water Development Appropriations Act with direction to initiate, as a priority action, a decontamination research and development project at these sites and vicinity properties, bring the program site total to 19. The Department's Oak Ridge Operations Office has the lead for implementing the program.

In fiscal year 1984, we expect to complete much of the cleanup work for contaminated properties near the DOE-owned Niagara Falls Storage Site at Lewiston, New York. Other remedial actions on this site will be described in my testimony on the Surplus Facilities Program. We are also planning to complete remedial actions at the Middlesex Landfill, New Jersey, and at the University of Chicago, Illinois. Material contaminated with uranium will be excavated from the Middlesex Landfill and temporarily stored at the nearby DOE-owned Middlesex Sampling Plant. At the University of Chicago, about 600 cubic feet of contamination in several laboratories will be removed and sent to the DOE disposal site at Hanford, Washington.

Preparations are underway to begin decontamination actions at the Maywood, New Jersey; Wayne/Pequannock, New Jersey; Colonie, New York; and Hazelwood, Missouri, sites which were added to the program in fiscal year 1984. Cleanup of residential properties at Maywood and Wayne/Pequannock is scheduled to begin March 1984, at Colonie in May 1984, at Hazelwood in July 1984. Our general approach to these projects is to give priority to cleanup of contaminated vicinity properties and to store the waste temporarily on each processing site. We also will take steps to prevent any further offsite contamination from these four sites. For the longer term, the Congressional direction is to decontaminate these sites. Because of the large volumes of waste involved, we have asked each of the three states in which the waste is located to designate a site for disposal within the state. DOE would then proceed to acquire the site and effect disposal. These actions are expected to require more than 10 years to complete at total costs exceeding $100 million. Due to the large quantities of material and the large costs associated with relocation, we will examine from the technical, environmental, and economic viewpoints, the alternative of stabilizing the wastes at their present locations for two of the sites, Maywood and Colonie, and report the results to Congress.

Other survey, preliminary engineering, and envirormental review activities are underway for the Albany Research Center at Albany, Oregon, the DuPont plant at

Deepwater, New Jersey, and the Middlesex Sampling Plant at Middlesex, New Jersey. We are also continuing monitoring of the Palos Park site in Illinois and the St. Louis Airport Storage Site in Missouri.

In fiscal year 1985 the cleanup of contaminated properties near the Niagara Falls Storage Site at Lewiston, New York, will be completed. We will continue the priority decontamination projects at Maywood, Wayne/Pequannock, Colonie, and Hazelwood. Cleanup of the residential properties in Maywood, the adjacent properties in Rochelle Park and Colonie, and Latty Avenue in Hazelwood will be completed and work will start on other vicinity properties. Design engineering and environmental analysis will be completed for the Albany, Oregon, site.

Grand Junction remedial action program

Under Title II of Public Law 92-314, Congress authorized financial assistance to the State of Colorado to limit radiation exposure resulting from the use of uranium mill tailings for construction purposes in Grand Junction, Colorado. This State/Federal cooperative effort with the State of Colorado is administered by the Colorado Department of Health through the Grand Junction Area Office. The remedial action provides for removal of uranium mill tailings from the premises of about 626 structures where radon daughter exposures exceed the Surgeon General's guidelines. Public Law 95-236 extended the time for property owners to apply for inclusion in the program, which has now expired, and increased authorized program funding. Federal funds cover 75 percent of the program costs with the State providing the balance. Fiscal year 1986 is expected to be the last year Federal funds will be requested for the program.

Through fiscal year 1983, work had been undertaken on 543 structures. In fiscal year 1984 the program will continue with radiological assessments and will initiate remedial actions at about 50 structures. In fiscal year 1985, the program will complete remedial actions on these 50 structures and will initiate and complete remedial action on 30 additional structures for a total of 623 structures out of the 626 to be completed.

Uranium mill tailings remedial action program

The Uranium Mill Tailings Remedial Action Program (UMTRAP) is responsible for conducting remedial actions at 24 former processing sites and several thousand contaminated vicinity properties as mandated by Public Law 95-604, "the Uranium Mill Tailings Radiation Control Act of 1978." Nine of the sites are designated as high priority, six as medium priority, and nine as low priority. The Act requires completion of the program within 7 years of the March 1983 promulgation of standards by the Environmental Protection Agency. Based on the results of an evaluation to assess the feasibility and budget impact of the mandated 7-year schedule, the Department has concluded that this schedule can be maintained. Project implementation is proceeding under baseline cost and schedule estimates that are consistent with the March 1990 completion dates. The current strategy is to focus near-term program activities on the higher priority sites and vicinity properties. Remedial actions are being conducted in accordance with cooperative agreements negotiated with the affected States and Indian tribes. Federal funds cover 90 percent of the remedial action costs (100 percent for those sites on Indian lands). The type of remedial action for the processing sites will be either to stabilize the mill tailings in-place, where feasible, or to remove the tailings to a new federally-owned disposal site. Engineering plans and environmental documents will be prepared for the cleanup and disposal operations at each site. The concurrences of the Nuclear Regulatory Commission (NRC) and the affected State or Tribe are required for each site remedial action plan. The program also includes the cleanup of contaminated vicinity properties. It is estimated that from 5,000-6,000 vicinity properties, mainly in the Grand Junction area but not covered by the Grand Junction program, may be found eligible for cleanup. The Albuquerque Operations Office has the lead role in implementing this program.

Specific accomplishments planned for the balance of fiscal year 1984 include the continuation of remedial action at Canonsburg, Pennsylvania, and initiation of remedial action at Salt Lake City, Utah. The Salt Lake City schedule has been adjusted to reflect the plans to relocate the tailings to a site near Clive, Utah. Cleanup also will continue at high priority vicinity properties near the Canonsburg, Salt Lake City, and Grand Junction, sites, and will be started at Edgemont, South Dakota, and Durango, Colorado. Remedial action plans will be completed, with State/Tribe and NRC concurrences, for Shiprock, New Mexico, and Gunnison, Colorado, and will be initiated for Durango, Colorado; Riverton, Wyoming; Lakeview, Oregon; Tuba City, Arizona; and Mexican Hat, Utah.

During fiscal year 1985 the work on the Canonsburg processing site and on the remainder of the 125 vicinity properties will be completed. The work at Salt Lake City will be brought to 30 percent completion and remedial action will start at Shiprock and be 60 percent completed. Onsite work also will be started at Durango. Approximately 215 vicinity properties, located at several high priority sites, will be cleaned up.

Surplus facilities program

This program provides for the safe management and disposition of the inventory of surplus radioactively contaminated Department-owned facilities from civilian nuclear energy development programs. The decontaminated facilities and sites are returned to other productive use where appropriate. All defense-related facilities are included in the Defense Nuclear Waste Management Budget. The facilities are grouped into about 55 projects under this activity. In addition, the program develops improved methods for decontamination and decommissioning which can be transferred to industry. A long range plan will be completed by the end of fiscal year 1984 to establish the overall schedule and priorities for sites currently in the surplus inventory. Priorities are established and work schedules are developed through analysis of legal, economic, and health/safety factors for each site. The Richland Operations Office has the lead field office role in implementing the program.

In fiscal year 1984, the major onsite cleanup and upgrading of storage facilities will be completed at the Niagara Falls Storage Site new Lewiston, New York. Work to recondition contaminated facilities will continue at the Mound Laboratory in Miamisburg, Ohio. This 10-year project, which is equally funded by this program and by the Assistant Secretary for Defense Programs, began in 1978 and will be 61 percent completed by the end of fiscal year 1984. Responsibility for the Shippingport plant will be taken over from Naval Reactors after all of the fuel has been shipped to the Idaho Engineering Laboratory. Projects offices will be established on the site by DOE and by the General Electric Company, which was selected in 1983 as the decommissioning operations contractor. Other activities in fiscal year 1984 will include completion of an action plan for work to be done at Monticello, Utah. A geohydrologic study and an engineering analysis of alternatives for long-term management of the Weldon Spring site in Missouri will be completed and a draft environmental impact statement (EIS) will be initiated. Decommissioning of several contaminated buildings at Argonne National Laboratory also will be completed.

In fiscal year 1985, the decontamination and dismantling of plant systems at the Shippingport Atomic Power Station will be initiated. The United States has proposed to the International Energy Agency that this be conducted as a limited cooperative project; details of the cooperation are under discussion. DOE will assure transfer of this technology to U.S. industry by providing opportunities for participation and by making the experience from the project widely available.

At the Niagara Falls Storage Site, the capping of the stored residues will be completed, the final EIS will be completed, and a DOE decision on the long-term management of these contaminated materials will be made. The decontamination and renovation of facilities will be continued at the Mound Laboratory and the project will reach 72 percent completion. Other activities in fiscal year 1985 will include: removal of contaminated material and systems at Santa Susana, California, completion of the environmental review process for the uranium mill tailings site at Monticello, Utah; issuance of a draft EIS for long-term management of the uranium and thorium wastes stored at Weldon Spring, Missouri; removal of the TRIGA reactor vessel at the Center for Energy and Environmental Research, in Mayaguez, Puerto Rico; and the decommissioning of building 38 at Argonne National Laboratory.

West Valley demonstration project

The objective of the West Valley Demonstration Project is to demonstrate the solidification process for disposal of high-level nuclear wastes under the provisions of Public Law 96-368, the West Valley Demonstration Project Act of 1980. An integrated production-scale development and demonstration project for treating the high-level liquid nuclear wastes at the Western New York Nuclear Service Center, near West Valley, will be carried out.

Major activities to be performed as part of the project include: (1) decontamination required to prepare existing facilities and equipment to accommodate the solidification project; (2) removal of the wastes from the underground storage tanks; (3) development, design, construction, and operation of systems and necessary supporting facilities for the solidification of the wastes; (4) acquisition of containers for the permanent disposal of the solidified waste; (5) temporary storage and transportation of the solidified waste to an appropriate Federal repository for permanent disposal;

(6) decontamination and decommissioning of the waste tanks, facilities, hardware, and material used in carrying out the project; and (7) disposal of low-level and transuranic wastes produced from project activities.

The total Project cost is now estimated to be $381.5 million (unescalated) through waste solidification (exclusive of final decontamination and decommissioning of the facility).

In fiscal year 1984 the major emphasis is on construction and decontamination. We plan to complete 60 percent of the construction of the vitrification Component Test Stand; procure the test stand melter, canister turntable, and other key components; complete construction and begin testing of waste mobilization and removal equipment in a one-sixth scale waste tank model; and complete verification testing for supernate processing equipment; complete decontamination of four radioactive areas and develop procedures for several more hot areas.

The funds requested for fiscal year 1985 will be used to test and adapt installed equipment to support the beginning of supernate processing in April 1987 and sludge processing in September 1988. In particular, the program will complete and operate the vitrification Component Test Stand; initiate design for conversion of the test stand to radioactive operation; complete decontamination of priority hot cells; and initiate procurement of supernate treatment, low-level waste treatment, and nuclear waste assay equipment.

NUCLEAR WASTE TECHNOLOGY

The fiscal year 1985 budget request for the Nuclear Waste Technology program is $13.3 million, a decrease of $1.0 million from the fiscal year 1984 appropriation. The funds are distributed among program elements as follows:

[In millions of dollars]

	Fiscal year—	
	1984	1985
Program element:		
Low-level waste	8.2	6.5
Program direction	5.6	6.3
Waste treatment	0.5	0.5
Total	14.3	13.3

The goal of the Nuclear Waste Technology program is to develop acceptable technologies for the treatment of civilian radioactive wastes. The major activities are: (1) the Low-Level Waste Program which provides technical assistance to States to develop regional capability for the disposal of low-level radioactive waste; and (2) the Waste Treatment Program which develops nuclear waste treatment processes and waste forms suitable for transportation, storage, and disposal in a geologic repository.

Low-level waste

Public Law 96-573, the "Low-Level Radioactive Waste Policy Act," assigned States the responsibility for disposal of commercial low-level radioactive waste (LLW) generated within their borders. The formation of regional compacts to carry out this responsibility was encouraged by the law. The goal of the Department's LLW program is to assist states in the development of an effective national LLW management system by 1986 and to evaluate this system in terms of operational efficiency by 1988. DOE involvement in active LLW disposal sites will also be completed by 1988.

During fiscal year 1984, the LLW program will complete the development of a regional LLW data base and continue its demonstration in compact regions; continue state/regional technical and financial assistance; and initiate disposal site stabilization and closure demonstrations at existing closed sites. The program is cooperating with the Office of Civilian Radioactive Waste Management to develop criteria and procedures for implementing the LLW site transfers to DOE as called for in the Nuclear Waste Policy Act of 1982.

In fiscal year 1985 the Low-Level Waste program will provide technical and financial assistance to a limited number of regions to support selection and operation of a new LLW disposal facility; support the correction of problems and stabilization at an existing disposal site; and support the utilization of advanced or innovative methods for the treatment of LLW.

Waste treatment

The objective of the Waste Treatment program is to develop and demonstrate technologies for the treatment and immobilization of nuclear fuel cycle radioactive wastes in forms acceptable for transportation, storage and ultimate disposal in a licensed repository. Specifically, high-level, transuranic, and sodium contaminated wastes are addressed. Over the years, methods for treating high-level and transuranic wastes have been developed. This program is now focused on determining the long-term reliability and maintainability of improved prototypical waste treatment systems and on testing and selecting acceptable waste forms for storage or permanent disposal in licensed facilities. The adequacy of these technologies is being demonstrated through their application to specific Departmental waste treatment efforts such as those at West Valley and Three Mile Island (TMI). Activities in this program are coordinated with other Departmental efforts related to fuel reprocessing; generation of special wastes; transportation; and terminal isolation of Department and commercial wastes.

In fiscal year 1984, waste solidification activities will focus on vitrification process controls and quality verification methods for demonstrating that the glass waste products meet required specifications. Specifications for transuranic wastes will be completed and transuranic waste treatment process development will continue. Criteria and guidance for shallow land burial of sodium contaminated wastes will be field tested and verified, with a final program report issued in 1985.

Activities in fiscal year 1985 will determine the operational reliability, safety, and process control flexibility of the ceramic melter system for solidification of high-level radioactive wastes. A series of ceramic melter system design, testing, operation, and decommissioning handbooks will be developed to aid future waste treatment users. Transuranic (TRU) waste treatment technology will be evaluated and further developed. Planned activities include assessment of treatment options; evaluation of nonradioactive treatment techniques; and conduct of radioactive tests. In addition, several proposed TRU treatment R&D programs which involve the actual treatment of existing TRU contaminated equipment in commercial plants will be evaluated. Evaluation of methods for treating spent nuclear fuel for interim storage and permanent disposal in a geologic repository will be initiated. Planning and evaluation of candidate materials and processes for a second generation, advanced waste form for high level wastes from less-aged nuclear wastes anticipated after the year 2000 will be conducted.

Three Mile Island program

The Three Mile Island (TMI) program is budgeted under the Converter Reactor Systems Program but is managed under the Office of Terminal Waste Disposal and Remedial Action. The objectives of this program are to acquire information and conduct R&D that will substantially enhance nuclear powerplant safety, reliability, and operation; and to ensure the means for safe disposal of abnormal nuclear wastes resulting from an accident.

In consonance with the Administration's policy that responsibility for commercial nuclear power activities resides in the private sector, the Department's TMI program is limited to research and development that will be of generic value to the development and safety of nuclear power and waste management. Responsibility for the costs of TMI cleanup remain with General Public Utilities (GPU), the owner of the facility.

The TMI activities are being implemented in accordance with a Memorandum of Understanding among DOE, NRC, the Electric Power Research Institute (EPRI), and GPU. The efforts of GPU are aimed at plant cleanup and recovery. The Department has developed a program work scope that enables obtaining important R&D information that would not otherwise be available from the TMI-2 cleanup effort. The DOE program is being conducted in a manner that avoids delaying the GPU cleanup schedule.

In accordance with a Memorandum of Understanding between DOE and NRC, the Department will acquire unique radioactive waste, including the damaged core, from TMI for research and development and for disposal. The cost of disposal will be reimbursed by GPU.

Two subprograms comprise the TMI program: the TMI Waste Immobilization and Reactor Evaluation Program and the TMI Data Acquisition Program. The fiscal year 1985 Budget Request for this program is $32.2 million as compared to $37.0 million in fiscal year 1984.

TMI waste immobilization and reactor evaluation

The objectives of this subprogram are: (1) to conduct research and development on immobilization of abnormal reactor waste products, and (2) to examine the TMI-2 reactor and core components in-situ and to support development activities associated with the reactor defueling; the data and information acquired will provide an improved basis for evaluating licensing criteria and requirements, analyzing causes and consequences of accident, and improving the reliability of the design and operation of light water reactors. This subprogram was initiated in fiscal year 1982.

The Reactor Evaluation activities include development associated with the examination, removal, and disposition of the reactor core and internals. This element also covers development of the special systems, equipment, facilities, and processes needed to accomplish the defueling operation, as well as performance of onsite examinations, tests, and evaluations required to handle the fuel effectively and expeditiously.

The development and engineering of systems, equipment and procedures for reactor plenum removal and storage and for reactor defueling and fuel transfer will be continued in fiscal year 1984. Reactor vessel head removal will be accomplished and core disassembly activities will be intensified with the goal of plenum removal in 1985 and the start of defueling in late 1986. The development work will be directed toward a thorough examination of the reactor internals and core. Substantial benefical information and data on the condition of the reactor core and other internal components will be obtained. In addition, preparations will be completed to perform examinations of the fuel and debris and other reactor internal components to characterize the accident effects. The knowledge gained from this program will provide data required for evaluating present licensing criteria and requirements; developing future licensing criteria; assessing and developing computer models used to analyze the course and consequences of severe accidents and means to mitigrate the effects of such accidents; and evaluating improvements to reactor design, operation, and maintenance.

The Waste Immobilization activities were initially focused on an effort to demonstrate the feasibility of vitrifying zeolite ion exchange materials. This effort was completed in fiscal year 1983. Activities are now focusing on other techniques for the treatment of abnormal wastes produced at TMI. Long term sample observation is being performed to provide a more extensive data base. The knowledge gained from this program will contribute substantially to the technology for processing and disposing of unique waste forms resulting from commercial nuclear powerplant abnormal operations and accidents.

TMI data acquisition program

The objective of this subprogram is to obtain R&D data of generic value to the safety of light water reactors. DOE and EPRI are sharing responsibility and costs for portions of this R&D program. Specifically, the Department is funding data gathering, research and development, and information transfer in the following major areas: instrumentation and electrical equipment survivability; behavior of radioactive products; data system and specimen archiving; and offsite fuel debris examination. EPRI has responsibility for R&D on mechanical and structual component reliability, pressure boundary recharacterization, and decontamination and dose reduction associated with the primary coolant system.

In fiscal year 1985, DOE plans to complete the in-situ and offsite examination of selected instrumentation and electrical components outside of the reactor vessel to ascertain their condition, cause of failure, and features which affect survivability. Data obtained will be used to upgrade qualification standards, regulatory guides, and operating and maintenance standards, in order to improve operation of nuclear plants and increase the likelihood of recovery from abnormal events. Efforts will continue on acquiring and analyzing solid, liquid and gaseous samples to identify how various radioactive isotopes, which were released within the containment building during the accident, were transported and deposited. This data will be valuable in assessing the existing models for fission product release which are used in nuclear powerplant licensing. Efforts to prepare for the offsite fuel debris examination will be completed. The Technical Integration Office will continue this program management activities at the TMI-2 site. The computer data bank system will continue to collect, store, and transfer the data and documentation generated by the DOE's program during the GPU cleanup effort.

Madam Chairman, this completes my formal statement. If there are any questions, I would be pleased to answer them at this time.

Mrs. LLOYD. Well, we do appreciate your excellent testimony, as well as Mr. Lawrence. And again, you've done a fine job and it's good to know that some of our goals are being achieved, and we look forward to your film presentation.

Anyone like to come around so you can see the film? Maybe you can turn it just a little more so they can see it, too. I think that's fine.

[Videotape presentation.]

Mrs. LLOYD. That was very fine; I appreciate that.

Dr. COFFMAN. I know your time is very valuable. We have a 7-minute tape on West Valley; it's at your discretion.

Mrs. LLOYD. Yes; and then we will conclude the hearings.

Dr. COFFMAN. OK, I'll put the other one on.

[Videotape presentation.]

Mrs. LLOYD. That was very good. I appreciated both films; they were well done.

I want to thank you for your attendance and your participation. For those of you that have been at our hearings this week, I think the quality has been very fine and I thank all of the participants, as well as I'd like to thank the staff of the subcommittee for a job well done.

If there's nothing further, the committee stands adjourned.

[Whereupon, at 2:30 p.m., the committee recessed, to reconvene at the call of the Chair.]

APPENDIX

SUPPLEMENTAL QUESTIONS AND ANSWERS FOR THE RECORD

Oak Ridge Associated Universities
(615) 576-3171
Post Office Box 117
Oak Ridge, Tennessee 37830

Institute for Energy Analysis

March 27, 1984

Ms. Debbie Martin
Subcommittee on Energy Research
and Production
Committee on Science and Technology
Room B-374
Rayburn House Office Building
Washington, D.C. 20515

Dear Ms. Martin:

Before departing for a two-week stay in Europe, Mr. Weinberg prepared the attached response to the questions raised in Mrs. Lloyd's letter of March 20, 1984.

Sincerely,

Bernice Corn

(Mrs.) Bernice Corn
Secretary to Alvin M. Weinberg

bc
Attachment

RESPONSES TO ADDITIONAL QUESTIONS FOR DR. WEINBERG

In response to your first question, the large HTGR is more forgiving than the LWR, as evidenced by the several occasions on which cooling was lost at Fort St. Vrain, yet the reactor was undamaged. On the other hand, there are accident sequences in HTGRs that can damage the reactor, and can possibly release radioactivity to the environment; the sequences, though unlikely, are hardly less likely than accident sequences in light water reactors. I therefore do not see very much difference between LWRs and HTGRs in respect to the public's perception of potential accidents.

The modular HTGR, by contrast, is, as suggested, inherently safe. This I regard as a very important attribute of reactors in the future. The public's attitude toward nuclear energy ought to be much more positive could it be convinced of the intrinsic safety of reactors like the modular HTGR and PIUS.

Incidentally, your statement that severe damage to a PWR core could occur in "less than a minute" is inaccurate. There are accident sequences where the core could become uncovered in less than a minute, but even in those instances melting would not start until about 20-30 minutes later. The operators probably have at least 10 minutes to take action to avert "severe damage to the core."

DEPARTMENT OF NUCLEAR ENGINEERING
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
77 Massachusetts Avenue Cambridge, Massachusetts 02139

Room: 24-109 (617)253-3806

March 30, 1984

Congresswoman Marilyn Lloyd
Chairman
Subcommittee on Energy Research and Production
Committee on Science and Technology
Suite 2321 Rayburn House Office Building
Washington, DC 20515

Attn: Ms. Debbie Martin

Dear Chairman Lloyd:

Thank you for the opportunity to respond to the additional questions raised in your letter of March 20 regarding the DOE budget request for Fiscal Year 1985. I have already responded to some of these questions by telephone to Nelson Milder of your staff, but would also like to submit the following written replies for the record of the February 7 Subcommittee hearing.

Question 1· In your report titled 'Nuclear Power Plant Innovation for the 1990s,' a statement was made about the cost of engineered safeguards becoming higher and higher on big nuclear power plants? Would you explain what engineered safety systems are compared to the "simplification" of safety design for small HTGRs which was also mentioned in the report?"

The basic safety goal of designers of all types of reactors is to prevent situations in which the rate of heat production in the nuclear fuel significantly exceeds the rate of heat removal by the reactor coolant. In such situations, overheating of the fuel will occur. If the imbalance between heat production and removal is sufficiently large, the fuel may be physically damaged, leading to the release of the highly radioactive products of the nuclear reaction process. Because of the potentially serious consequences of such a release to public health and safety, another key safety objective of reactor designers is to limit the access of radioactive materials released from the fuel to the external environment. This is the principal function of the reactor containment system.

Two basic conditions can cause fuel overheating: an abnormally high rate of heat production in the fuel, or a partial or complete loss of the heat removal capability. Two corresponding characteristics of nuclear reactors are thus central to the prevention of fuel damage: reliable mechanisms for ensuring the rapid termination of the chain reaction in the fuel; and reliable mechanisms for emergency core heat removal. In each case, the mechanisms in question may be an integral feature of the reactor's response to the original perturbation, or alternatively they may be activated by the intervention of external engineered systems. The relative reliance on passive and active safety mechanisms varies depending on the type of reactor.

In conventional light water reactor designs, primary reliance is placed on external engi-neered safety systems for emergency core heat removal. Several auxiliary cooling systems with backup power supplies and redundant instrumentation are provided in the event that the primary cooling system fails. As light water reactor power plants have increased in size and core power density, the demands on the engineered safety systems have increased correspondingly. One of the consequences of the high power density in modern LWR cores, for example, is that the time interval between the interruption of primary cooling and the onset of severe fuel damage has declined. The required response time for the auxiliary cooling systems has consequently also been reduced.

The combination of the evolving physical characteristics of LWR cores and the societal preoccupation with the consequences of extreme but very unlikely accidents has led to a proliferation of safety requirements for LWR plants. More often than not, these have resulted in the addition of new engineered safety systems or the reworking of existing ones. Much of the increase in the direct capital cost per kilowatt of LWRs can be attributed to these changes. Of comparable and perhaps greater significance has been the indirect economic impacts of the added safety systems. In particular, the greatly increased complexity of LWR plants has contributed to lower labor productivity and management-induced delays during construction.

The relative dependence on passive versus active safety mechanisms is appreciably different in the case of the small HTGR. A key difference is in the area of emergency decay heat removal. Even for large HTGR cores, the low power density, high thermal capacity, and good high temperature characteristics of the graphite moderator mean that a great deal more time is available between the interruption of primary coolant flow and the onset of severe fuel damage than for a large PWR. Reducing the core size creates the added possibility that the core decay heat can be removed entirely by passive thermal conduction and radiation. For certain combinations of core geometry, size, and power density, in the event of a loss of coolant accident no active safety systems or human actions would be required to prevent the fuel from reaching the temperature at which major fission product release begins. The potential opportunity for design simplification created by this 'inherent' safety feature of small HTGR cores is evident.

Question 2: "Do universities have the facilities to participate, in a major way, in the mainline nuclear fission r.&d. program?"

A major element of advanced reactor development programs is the development and testing of large-scale systems and components. Clearly, the universities cannot match the capabilities of the large equipment manufacturers and the national laboratories in this area. However, this does not mean that only 'paper studies' are appropriate in an academic environment. There are, in fact, several areas of experimental research and development in which some universities are well equipped to play an important role. This is the case, for example, in the area of advanced instrumentation and control, and in the development and testing of advanced materials for use in nuclear environments. It is also important to note in this context that sponsored experimental research programs are a vitally important component of graduate education in the nuclear engineering field, as in other fields of engineering.

Question 3: "Dr. Weinberg has spoken of a 'second nuclear era.' If such an era were to come to pass, what role should universities play in it?"

A future return to the nuclear option in the United States obviously would not be possible in the absence of professional engineers trained in the fields required for the design, construction and operation of nuclear power plants and fuel cycle facilities. In a 'second nuclear era,' the universities would have a central role in assuring the supply of such engineers in adequate numbers. In this regard, it is unrealistic to expect that a future nuclear industrial revitalization could be staffed entirely by professionals whose engineering education was obtained in other fields (e.g. chemical, mechanical, or electrical) and whose nuclear training was acquired on the job. The present nuclear industry has a strong need for graduate engineers with university training in areas unique to a nuclear engineering curriculum, and this would certinly also be the case in the future.

Question 4: "Please review the status of nuclear engineering programs, both in the education of nuclear engineers at the undergraduate levels, and in r.&d. related programs within the university structure."

A review of the current status of nuclear engineering undergraduate and graduate programs was published in the February 1984 issue of Nuclear Industry, the journal of the Atomic Industrial Forum. A copy of this article is attached.

Question 5: "Please delineate for the Committee your views on possible areas in which the university community could contribute to the Federal nuclear fission r.&d. program."

It is my understanding that this question pertains in particular to nuclear power plant research and develop-ment programs, and my response has been prepared with this in mind. Before going further, however, I would like to emphasize the importance of past university research efforts in the nuclear fuel cycle field, and to note the contributions that can be expected in this area in the future, including nuclear waste management.

Areas in which the university community can contribute to Federal reactor research and development efforts can be grouped into three catagories:

(i) Near-term research and development for operating reactors

(ii) R.&D. for lifetime extension of operating reactors

(iii) Advanced reactor research and development

With regard to the first of these, there are many examples, far too numerous to mention, of ongoing research programs involving universities. A recently initiated program involving DOE, Baltimore Gas and Electric, and the University of Maryland's Nuclear Engineering Department is perhaps especially worthy of note in this regard, because of the example it provides of constructive research collaboration between government, industry and the academic community in an area of direct benefit to industry.

Regarding reactor lifetime extension, no Federal program currently exists. In the longer term, however, this is an area that is likely to become increasingly interesting to the nation's utilities, given the very high costs of replacement capacity. It is also an area in which the early participation of the universities could yield insights and creative solutions at modest cost.

The third area -- advanced reactor research and development -- also offers many potential opportunities for university participation. The proposed program of research on the modular HTGR concept is technically well-suited to university participation. An illustration of the opportunities available here is provided by the attached research prospectus recently prepared at M.I.T. entitled, "A Study of the Technical and Economic Potential of the Modular HTGR." In the past, however, there has been very little funding available for university research in this area.

There are also important opportunities for university participation in the development of advanced LWR designs. For various reasons, partly related to the regulatory climate, neither reactor vendors nor utilities have been willing to take the initiative in rethinking design approaches in certain safety-related areas, even though the longer run benefits of doing so are acknowledged. The universities may have an important catalytic function in this regard. An example of what is meant by this is provided by the attached document, "Refinement of Light Water Design Goals: A Plan for Action," also recently prepared at M.I.T. Until now, the universities have had virtually no participation in this area. Indeed, by and large neither has the Federal government.

The situation in the liquid metal cooled fast reactor field has been somewhat different. There has, of course, been a large Federal r.&d. commitment to this technology, and as part of the Federal program a fixed sum has been allocated specifically for the main contractors to pass through to the universities. From the universities' perspective, this scheme has had two problems: the total amount allocated to the academic community has been very small (less than $1 million/yr, out of a total annual budget for the LMFBR of several hundred million dollars); and the contractors who have administered the funds have tended not to encourage university researchers to depart from the immediate objectives of the program, an approach which has failed to exploit fully the comparative advantage of the universities in this area.

Finally, I would like to stress the importance of university participation in advanced reactor research and development to the educational mission of the universities in the nuclear engineering field. The primary purpose of the universities in this area is, of course, to train graduates who will ultimately be capable of assuming leadership positions in government and industry. As important as the goal of completing and operating the present generation of reactors safely, reliably, and economically undoubtedly is to the future of the nuclear power option, this is not enough to attract students of the calibre needed to play a leadership role in the field. Conversely, a well-directed Federal program to aid in the development of advanced nuclear power plant systems better suited to the needs and capabilities of the U.S. electric power industry, in which the universities are seen to be participating, can be effective in attracting the high quality students that the industry will certainly need if it should decide to return to the nuclear option in the future.

Thank you again for the opportunity to present my views on these important issues.

Yours sincerely,

Richard K. Lester

Richard Lester
Associate Professor

RL:ewp

Enclosures

A STUDY OF THE TECHNICAL AND ECONOMIC POTENTIAL OF THE MODULAR HTGR

Co-Principal Investigators

Professor David Lanning
(617) 253-3843

Professor Lawrence M. Lidsky
(617) 253-3808

Department of Nuclear Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

January 1984

THE MHTGR INITIATIVE

A. Introduction

The MIT Nuclear Engineering Department has recently completed the first phase of a major study of the possible role of technological innovation in determining the future direction of the nuclear power industry (Ref. 1). In particular, an examination was made of the role that nuclear power plant design innovations might play in making nuclear energy a more attractive generating option for U.S. electric utilities in the 1990's and beyond. In addition to noting the potential for incremental improvement of existing LWR's, the participants also considered the potential capabilities of a wide range of other reactor types. The study considered both the commercial potential of such innovations and the feasibility of bringing them to market.

The possibility that a reactor type previously considered noncompetitive might now become the option of choice is a result of several fundamental technological and economic developments. First, the sharp decline in the expected growth rate of nuclear power plant capacity coupled with the more promising outlook for the availability of reasonably-priced uranium resources means that uranium conservation need no longer be a dominant objective of reactor designers during the next few decades. Second, both the much lower than previously experienced load growth rate and the manifold difficulties associated with large incremental additions to individual system generating capabilities argue for plants with smaller unit size. Even in the face of predicted need for substantial replacement of existing base load in the mid 1990's, it is likely that smaller unit size and predictable construction times will be seen as high priority attributes. Finally, utility experience indicates that design simplicity and fault tolerance (so called "inherent safety") can play an essential role in simplifying the licensing and regulatory processes. A simpler, more forgiving reactor design would also place a smaller burden on the utility operating staff.

Although the present difficulties in the U.S. nuclear power and electricity generation industries might at first be thought to mitigate against deployment of any new reactor type, the hiatus in nuclear ordering actually increases the possibility that a new design could be commercialized in time for the next round of orders. A new design with substantially different real (and perceived) attributes might even be a prerequisite for a new round of orders. However, for deployment in the time frame considered, it is essential that there already exist a substantial body of operating experience and industrial capability. This constraint was applied to all candidate reactor types.

With these considerations in mind, the study first concluded that the first rank targets of technological innovation were:

- lower and more predictable plant capital costs;
- shorter and more predictable construction lead times;
- higher reliability;
- reduced financial, health, and safety risks (perceived and actual);
- optimized plant size.

Based on the conclusions of the assessment study and using these targets as measures of merit, the MIT Nuclear Engineering Department initiated a major study of the potential of the modular HTGR (MHTGR). This document describes the present status of the MHTGR program and outlines our long range plans.

B. Discussion

1. MHTGR Advantages

Gas-cooled reactor systems have several inherent safety-related features that open numerous possibilities for reactor designers. In particular, the low specific power density, low excess reactivity, and the chemically inert, single-phase coolant of helium-cooled graphite-moderated reactors lead to longer transient response times and larger safety margins. These advantages are features of all HTGRs, both large and small. The MHTGR's are designed to further enhance these safety characteristics by utilizing a small reactor, such that even under extreme accident conditions (e.g., total loss of core cooling capability coupled with complete failure of the control system), the fuel cannot reach temperatures resulting in significant fission product release. The nominal size range for reactors possessing this attribute is 200-250 MW_{th}.

Power plants using small standardized modules might have significant economic advantages. Savings from centralized serial production would lower the specific cost of individual modules. Serial production also leads to more predictable pricing and delivery schedules. These economic benefits would be substantially enhanced if it could be demonstrated that particular safety systems and design specifications required for LWR's were not needed in properly designed MHTGR systems. For example, it is possible that the MHTGR will not require all the expensive containment and accident mitigation systems required for LWR plants. In this event, both the materials and construction techniques required for the balance of plant could emulate fossil plant practice rather than the substantially more expensive reactor grade construction.

Central station power plants would probably be composed of 4-12 identical MHTGR's; each with nominal power output of approximately 200 MW_{th}. Such redundancy can, in principle, lead to simple load matching and very high availability. With suitable modularity of the balance of plant one can almost guarantee that the station never goes completely off line. In addition to these operational advantages, there are equivalent economic advantages of modularization: staged operation, optimum load matching, early addition to load base, etc.

Finally, the claimed freedom from investment and public safety hazards will be easy to verify because design basis accidents can be demonstrated experimentally. Entirely independent of the actual risks associated with improved versions of existing nuclear power plants, the easily perceived conversion to a significantly different, more forgiving, technology is considered to be an important advantage.

2. Gas-Cooled Reactor Experience

Gas-cooled power reactors have accumulated over 650 reactor years of operating experience during the past twenty-seven years. Much of this represents the cumulative operation of the MAGNOX and AGR reactors in the United Kingdom. These reactors are carbon dioxide cooled and operate at somewhat lower temperatures than the helium cooled reactors. Although France and the USSR have also operated gas cooled reactors, the most directly applicable experience with the helium-cooled high temperature reactors of interest here is available in the U.S. and the German programs.

The first U.S. plant was the 115 MW_{th} Peach Bottom development unit operated by the Philadelphia Electric Co. from 1967 through 1974: Peach Bottom demonstrated high efficiency (35%), high availability (88%), and exceptionally low specific operating personnel exposure. The substantially larger Fort St. Vrain Plant (842 MW_{th}) has been operating at full power only since November 1981, but has already achieved net efficiencies of 38.5%. Even though Fort St. Vrain experienced many design-specific mechanical difficulties during its start up phase, the radiation exposure of operating personnel was still less than 2%

of that received by the staff of conventional LWR's.

The 50MW_{th} (15MW_e) AVR reactor in the Federal Republic of Germany is a direct ancestor of the MHTGR that will be a major focus of our study. AVR is a pebble bed reactor utilizing continuously circulating fuel to achieve core uniformity, reactivity control, and high burnup. AVR has been operational since 1967 with average annual availability of 75% to 90%. AVR has also exhibited the extremely low level of primary circuit activity noted in all gas cooled reactors. The follow-on 300 MW_e THTR-300 pebble-bed reactor achieved criticality in October 1983.

The present U.S. MHTGR program is coordinated by GCRA, the Gas-Cooled Reactor Associates, which represents utilities with approximately one-third of the nation's generating capacity. Primary financial support for the program is furnished by DOE as part of the total HTGR program. Major participants in the program include GA Technologies, General Electric Company, Combustion Engineering and the Oak Ridge National Laboratory. In addition, both United Engineers and Constructors and Bechtel Group, Inc. have supplied architect/engineer services.

3. MIT's Role

We believe that MIT can play a significant role in the ongoing technical and economic assessment of small gas cooled reactors. At the same time, we hope to contribute to the development of trained personnel to move into this new area if it is appropriate to do so. The Nuclear Engineering Department is particularly interested in doing analyses and design studies aimed at determining the potential for using such reactors for electric power production in the U.S. However, we are in contact with other groups at MIT and elsewhere that are considering the applicability of the MHTGR to process heat and cogeneration.

Economic analyses of MHTGR systems will also serve as input to a proposed new effort to define a rational structure for utility/PUC/NRC interactions with respect to power production capacity planning.

C. Research Program

1. Scope

We have begun a comprehensive study of the MHTGR concept involving research, teaching and industrial involvement. Our initial intent is to help determine whether the MHTGR is suitabl for deployment in the decade of nineties. If the answer affirmative, we expect then to play a role in optimizing th design, to act as an independent research resource and, of course, to provide graduates trained in relevant areas.

We cannot, of course, be equally active across the entire spectrum of issues involved in MHTGR research. We will attempt to be cognizant of all areas but will concentrate our initial efforts on safety, investment, and licensing issues. Our early projects involve questions of source term/core design interactions, applicability of safety goals, incentives for fuel quality improvement and definition of design goals. In the somewhat longer term, we plan to consider such questions as operational optimization, high temperature designs and international proliferation risk analyses. If the research area does develop and grow, then we expect also to be involved in detailed studies of more narrowly focussed questions raised by our more general considerations.

2. Current Programs

We have begun active work on four research projects; several others have been identified but wait resolution of funding questions.

a. Reactor Core Design

Development and use of simple models to determine the trends and characteristics of a range of possible modular gas cooled reactors. The prime focus will be the interaction of core design and fuel characteristics in determining the source term in "heat up events". We will also seek to understand the effect of reactor core configuration, fuel type, and power level on control system requirements, operational heat removal, decay heat removal, accident response, balance of plant configuration, refueling characteristics, and external fuel cycle.

b. Economics of Scale

Significant economic benefits are potentially available if advantage is taken of serial off-site fabrication, simplified plant construction, improved licensing (standardized modules), possible reduced safety envelope. The dominant issue to be resolved is whether the reduced specific plant costs available via serial production techniques offset the strong economy of scale dependence traditionally accepted by the nuclear electric industry. Industry experience and theoretical models of manufacturing productivity and serial production learning curves will be studied for relevant industries (chemical, aero, coal fired electric, etc.). Major economic benefits would follow from stepwise construction of the power plants, especially if the shutdown period for installation of additional modules could be minimized. This possibility will be studied.

c. Source Term Effects

The inherent safety feature of some MHTGR's suggest many possible savings in balance-of-plant design, licensing requirements and plant security. Some of these savings are highly dependent on whether licensing regulations are specifically written to account for the particular features of the MHTGR. Although such new regulations may reasonably be advocated when the MHTGR is better developed and tested, reliance on new regulations at this time seems premature. We will concentrate on the application of existing regulations to the HTGR with particular attention given to the question of confinement/containment. We will determine which existing requirements are limiting and determine whether these requirements are compatible with economical MHTGR deployment.

d. Optimum Modularization

The possibility of modularizing the nuclear heat source as well as the traditionally modular steam generating and turbine systems, affords a new degree of freedom. The effects of the order of modularization (i.e., the particular combinations of individual sizes and number of modules) and of the type of interconnection are not well understood. High order modularization can, in principal, lead to simple load matching and very high availability. On the other hand, a large number of individual units requires a more complex and expensive interconnection scheme and possibly more complex plant control requirements. We will classify and begin the assessment of the various possible modularization schemes.

C.3 Personnel

The program is under the co-direction of Professors David Lanning and Lawrence M. Lidsky; six students are currently working on the project. Eventually, it is expected that the program will involve a total of three to four faculty and ten to twelve graduate students. Because of the uniquely interesting variety of research problems involved, we expect faculty and student participation will be limited only by funding constraints.

C.4 Estimated Cost vs. Time

We have chosen a five year planning horizon as compatible both with graduate student involvement and with external time scales. We believe we can meet the program objectives if we maintain the present level of faculty/student effort through 84; increase this level to 3-4 faculty and 10-12 students during 1985; and maintain that level during 1986-88. See Table 1.

At present, in order to get the program started, the two faculty members directing the program are essentially donating their time. In addition, the six students are supported by a variety of assistantships and limited term fellowships. In this manner we will initially be operating at an effective level of effort corresponding to an annual funding of $250,000. However, the program cannot continue at this level for very long without obtaining outside funding support.

Our plan is first to try to obtain the funds necessary to maintain the present student involvement. To do this we need to obtain additional support for two students during the Spring semester, and for four students during the summer of 1984. Once this is achieved we hope to gradually increase the funding to a level sufficient to support 3-4 faculty and 10-12 students.

The corresponding funding profile is shown in Table 1.

Thus, in order to maintain our present two faculty, 6 student level of effort through 1984 we will need to obtain $35,000 for the Spring term, $36,000 for the Summer term, and $123,000 for the Fall term--for a total of $194,000 during 1984. Then, to increase this effort to 3-4 faculty, 10-12 student level of effort eventually planned, we will need to obtain $340,000 - 550,000 during 1985 and $550,000 during each of 1986, 1987 and 1988.

D. Funding Plan

We have made an effort to maintain strong, open, effective communications with all participants in the area. We feel that this is good policy in any event but especially so in light of the special aspects of this field. In a similar fashion, we hope to have our research supported by a number of sources, both private and governmental. We have been materially aided in identifying and approaching such sources by GCRA and we plan to continue to use GCRA's good offices to assure that MIT's program is well integrated with the national program. We prefer that individual sponsors contribute to general MHTGR project funding (i.e., without specific allocation) because in such cases, we are free to optimize the use of all available funds. Nonetheless, we welcome explicit funding to support specific research projects within the overall group effort.

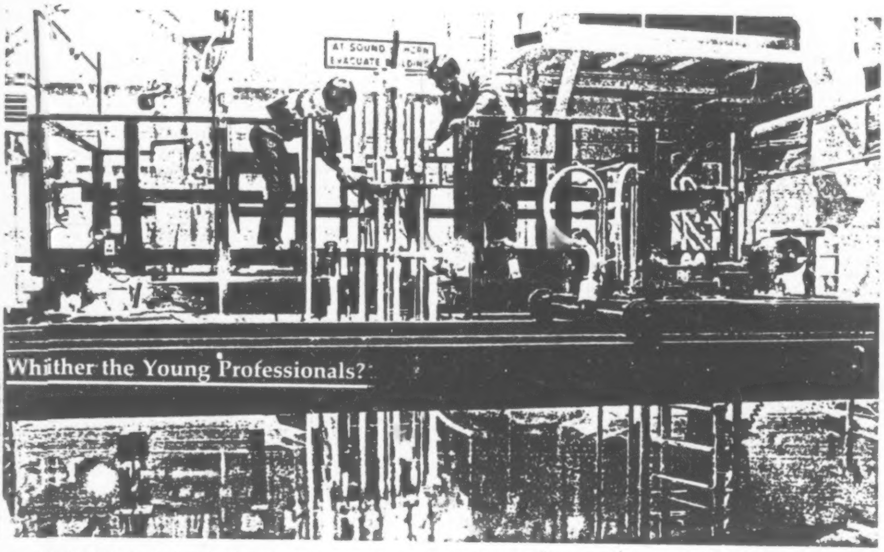
E. References

1. Lester, R.K., Driscoll, M.J., Golay, M.W., Lanning, D.D. Lidsky, L.M., Rasmussen, N.C. and N.E. Todreas, "Nuclear Power Plant Innovation for the 1990's: A Preliminary Assessment," Department of Nuclear Engineering, MIT, September 1983.

oooooo supported
______ funding required
------ tentative

MODULAR HTGR ASSESSMENT PROGRAM AT MIT-NED

Student	Project	1984			Support Required/Term 1985			1986		
		Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
James Del Favero	Reformer design & Safety	oooooooooo								
Andy Wolford	Cost factors and optimization	[——	——————	——————	——————	——————	——————	------	------	------
Joy Maneke	Source term and containment requirements	——————	——————	——————	——————	——————	——————	------	------	
Mike Izenson	Core design and safety assessment	oooooooooo	——————	——————	——————	——————	——————	------	------	
Hamid Rafati	Systems control	[——	——————	——————						
Ray Coxe	Cost uncertainty reduction, including fuel management	oooooooooo	oooooooooo	——————	——————	——————	——————	------	------	------
"New"	PRA for cost-benefit trade-offs and comparisons	------	------	——————	——————	——————	——————	——————	——————	——————
Total Student Roster,		6-8	6	8	10	10	10	12	10	12
Total Student Support Per Term:		2	4	6	8	6-8	8	10	6-8	10
Faculty										
D. Lanning , L. Lidsky		——————	——————	——————	——————	——————	——————	——————	——————	——————
Others(R.Lester,N. Rasmussen, etc.)		oooooooooo	oooooooooo	oooooooooo	oooooooooo	oooooooooo	——————	——————	——————	——————
Funding/Semester K$		35	36	123	---	---	---	200	250	200
Annual Funding Req. K$		194			340-550			550		



Whither the Young Professionals?

PENNSYL IA STATE UNIVERSITY

PENN STATE STUDENTS INSPECT CONTROL ROD DRIVE ABOVE TRIGA RESEARCH REACTOR POOL

Enrollment Dips, And Academia Frets About Its Ability To Train

Many in industry, government and academia today fear the public debate surrounding the safety and economics of nuclear energy will seriously deter industry's ability to attract the best and the brightest, particularly among the ranks of young professional engineers.

Although recent data show an overall balance between the supply of students specializing in nuclear fields and industry's need for such expertise, sources believe the statistics presage a dwindling talent pool which could prove devastating when nuclear power resurges at some future point.

"If we do not maintain the capability to educate in this area, we will suffer serious harm," warned Dr. Warren Witzig, head of nuclear engineering at Pennsylvania State University and an industry veteran. "Why? Because there will be increasing use of nuclear energy as time goes by as well as increased use in institutional areas such as food preservation."

The Downward Trend

The cause for alarm stems from nationwide enrollment trends in nuclear engineering programs at all levels of study. The number of students seeking undergraduate or advanced degrees in the discipline versus those pursuing other engineering careers has dropped markedly from the peak years of the mid-1970s; only in the last two years have the figures indicated the slightest rebound.

The major reason for this pattern, according to sources in both industry and academia, is the average student's perception of nuclear as a high-risk career. Recent cancellation of the Clinch River breeder reactor project last year, the recent abandonment of Marble Hill and the decision to convert Zimmer, to coal will add thousands of qualified employees to the job bank in 1984. Yet it is feared that enrollment figures, so closely tied to indicators of industry's health, will dive as a result of such shockwaves.

And the chain reaction does not stop at the student level. Entire nuclear engineering programs have died along the way, and frustrated members of academia are leaving the ivory towers for higher-paying jobs with private industry or the government. The scenario played to its natural end is this: if the nuclear engineering programs become extinct, so will the seedbed from which the ideas come.

Wither the Students?

Formal nuclear engineering education began at the graduate level in the mid-1950s, when the government declassified sensitive information from the Manhattan Project and the national laboratories passed to universities the task of retraining scores of engineers and scientists from myriad fields. By the 1960s, interest proved high enough to merit formation of undergraduate programs, and enrollment and degree figures for studies at that level remained healthy until the peak 1977-1978 academic year.

According to statistics for 1982 gathered by the Department of Energy and the Oak Ridge Associated Universities, 824 bachelor of science degrees were conferred during 1977-1978, as well as 487 masters and 110 doctorates. This was followed by three years of steady decline in undergraduate degrees until 1982, when the number of bachelor degrees inched upward by 2 percent to 6[illegible].

Dr. WARREN WITZIG

. . . the need will grow

Masters programs in nuclear engineering exhibited an even pattern during the 1970s until the growth curve for the number of advanced degrees awarded dropped to a low of 315 during the 1980-1981 academic year. In 1982, the level of masters degrees experienced a moderate 8 percent growth, but the number of students receiving Ph.Ds. fell by 4 percent to 126. Enrollment, however, picked up during the 1981-1982 school year: 16 percent for undergraduates, 8 percent for masters, and 5 percent for Ph.Ds.

The upturn of the last two years is cause for some optimism, but does not indicate a definite reversal in the supply side. "Continued growth in nuclear engineering education programs will be required to meet future staffing needs," concluded DOE in its report. "While cutbacks in some parts of the industry have recently contributed to reducing the backlog in vacancies, the continuing low enrollments are cause for concern."

Hiring Projections Fluctuate

Prospective nuclear engineering students, more so than those contemplating other, less specialized engineering professions, must be assured of returns on their investments upon graduation. Until recently, one of the most positive pieces of evidence a nuclear engineering faculty could present to students was industry's sound employment record.

Today, opinions vary as to the short- and long-term demand for the trade. For nuclear utilities alone, recently released data compiled by the Institute of Nuclear Power Operations for 1983 show that hiring levels of its 57-member utilities have risen since 1981, but the long-term employment goals of this sector have dropped in comparison to forecasts made in previous years.

INPO's third annual survey of nuclear utilities' manpower needs shows there has been an increase of 1,72[illegible] nuclear-related positions compared with results obtained in 1981 and 1982, but this is offset by declines in three areas: there were fewer vacancies reported by member utilities; the projected level of employment growth over the next 10 years has dropped since 1981; and there were fewer incidences of employees moving to related jobs at other companies or leaving a utility for non-nuclear positions.

The Ten-Year Curve

When measured against similar projections made in 1981, this translates into a 38.6 percent drop in projected requirements for additional personnel over the next 10 years. Overall, the INPO study reveals that its member utilities will need to attract and hire a total of 28,803 additional management, technical and professional manpower by 1993 to fill positions left open by vacancies and growth.

The study, however, shows wide fluctuations in the number of newly created jobs allotted for the 10 years following each survey. In 1981, for example, expectations for employment growth alone accounted for 13,700 new jobs. The growth level

Competition For Staff

Government, Industry Lure Potential Faculty

Dr. JOHN LUCEY
. . . need for new blood

Symptomatic of the enrollment decline and tightened purse strings of industry and government, nuclear engineering departments are finding cause to worry about a trend which has plagued the entire engineering field during recent years—a shortage in faculty.

Dr. John Lucey, in charge of the University of Notre Dame's nuclear engineering program and chairman of the ANS education division, acknowledged that the problem with nuclear faculties is not as severe as the overall engineering crisis, but points out that it is difficult to get good, young teachers in [illegible] field, much less nuclear engineering.

"Education works best when you keep bringing in new blood," he said. "If you don't have that continuous environment of new ideas, then everything just gets stale."

Ph.D.s Stray from Academe

Recent statistics show that a growing number of Ph.D. students are foregoing their traditional places in academia for better-paying jobs in government or the private sector. Moreover, fewer than a tenth of recent engineering students graduating with honors, and only a quarter of those heading for graduate school, plan to seek teaching careers, according to surveys conducted in 1977 and 1982 by Tau Beta Pi, the national engineering honor society.

Recently, a special joint task force of the American Association of Engineering Societies and the American Society for Engineering Education explored the teaching crisis. A poll of the nation's 290 engineering schools showed that in the 1981-1982 and 1982-1983 academic years, there was a slight drop in the number of budgeted faculty positions which were not filled. On the other hand, there was a 20-[illegible] percent gap in the number of slots which should have been authorized to provide quality education to nearly a half million engineering students at all levels. Because of this shortfall, classes have had to be dropped, teachers' workloads are heavier, and university administrators see no need to allot more positions when vacant ones are not being filled.

The task force reached several conclusions. At the Federal level, a new faculty assistance program should be initiated to lighten beginning teachers' loads during their first two years and to assure them of summer salaries in order to continue research. Within academia, institutions should modernize their research equipment and facilities and pay salaries comparable to the marketplace.

Industry's Responsibility

Industry, for its part, should expand its contributions to graduate fellowship programs, universities and research efforts. It also should provide summer employment; encourage employees to give lectures or serve as adjunct faculty; and donate lab equipment or allow access to facilities.

While it could be argued that the dwindling supply of nuclear engineering students would merit the need for less, not more, teachers, academicians again are worried about quality.

"I am personally convinced that nuclear engineering is going to be important in the future," said University of Washington's Dr. Gene Woodruff. "I don't know exactly when, but there is going to be a very, very severe shortage of qualified faculty."

Cautioned North Carolina State's Dr. Paul Turinsky: "If things get really negative, to a point where faculty can't get students to work for them at the graduate level, where it can't get money to do its research, or when the faculty cannot fulfill its professional needs, the good folks are going to leave. Left behind will be the ones who perhaps are not your best."

—T.A.N.

dropped to a low of 3,291 the following year, but doubled in 1983 to 6,803.

The need for senior and licensed operators, training support staff, shift supervisors and health physicists will be the greatest during the coming 10 years, but requirements for nuclear and reactor engineers will expand by about 16 percent, according to INPO's data. By 1993, there are expected to be 1,666 nuclear and reactor engineers employed by this sector alone, representing 235 new slots. This reflects the second largest level of growth in the engineering category for nuclear utilities, exceeded only by projections for approximately 19 percent more radiation protection engineers by that date.

In all engineering disciplines, the responding utilities plan to hire only for replacement after 1989, adding no newly created positions after that. The growth for nuclear engineers is expected to peak by 1985, after which utilities will hire at a rate of about 60 nuclear engineers a year for replacement.

DOE Sees Larger Requirement

In contrast to INPO's picture of utility employment, DOE's 1982 study into total energy-related manpower needs between 1981 and 1990 estimates a substantial increase in all nuclear-related employment, encompassing both energy and defense-related work.

Accounting for industry uncertainty, DOE based its projections on current plant construction activity, adjusted for cancellations and delays, and also on expected growth in operation and maintenance requirements, waste management activities, health physics, fuel processing and fabrication, and industrial safety. By 1990, it estimated a need for 45,000 additional personnel over the 1981 level of 250,000 employees.

As did INPO, DOE concluded the largest percentage of growth will be seen by reactor operators, at 79 percent, while engineering positions are expected to increase 16 percent by 1990. Also paralleling INPO's estimates for utilities, DOE projected the entire industry's replacement needs will be twice those of its growth positions over the decade.

Dr. PAUL TURINSKY
. . . fewer superstars

The DOE report also indicates that the slight increase in enrollment it forecast for the period 1981 to 1983 will not necessarily offset the substantial decline in nuclear engineering degrees awarded between 1978 and 1981.

Further, "nuclear engineering differs from other fields in that nearly all the graduates end up in activities related to the DOE's mission (energy or defense)," states the report. "If a supply shortfall does occur, it cannot be solved by bidding up salaries to hire nuclear engineering graduates away from other activities, because at present so few are engaged in activities not related to energy or defense."

ANS Projects 15% Gap

Consolidating all of the efforts to measure industry demand and student supply completed at that time, the American Nuclear Society last summer made its own projections and concluded that there will be a 15 percent shortfall in nuclear engineers during the period 1984 through 1990. ANS made its predictions based on the most pessimistic assumptions, accounting for plant cancellations if construction had not progressed beyond a given level and no new orders in the foreseeable future.

James Coffey, newly appointed director of the Tennessee Valley Authority's nuclear division, also agrees that there is going to be a fairly great need for nuclear engineers in the future, even taking into account INPO's manpower data for nuclear utilities. "Speaking for TVA, I see the need to continuously put in at the bottom of the ladder nuclear engineering graduates, and I intend to do that," said Coffey.

For 1984, TVA intends to hire 14 nuclear engineers, a level that has picked up somewhat from two years ago but still not as high as TVA's years of peak nuclear construction. This compares favorably to its need for 36 electrical and 46 mechanical engineers required for TVA's enormous steam and coal-fired capacity.

Tough Years Ahead for Graduates

Noting a slight drop in the number of recruitment visits to the Penn State campus, however, Witzig and his students conducted their own industry survey to gauge job prospects for 1983 graduates. Questionnaires were sent to 111 firms representing utilities, vendors, architect-engineers, government, and consulting firms, of which roughly 46 percent responded.

They found that fewer nuclear engineering graduates would be hired in 1983 due to the economy, the drop in electricity demand, the need for experienced personnel rather than entry-level employees, plant cancellations and delays, or the existence of sufficient nuclear support staff. Utilities would provide the greatest numbers of jobs for graduates with bachelor of science and masters degrees in nuclear engineering, followed by vendors.

Although many companies could not elaborate on their long-range goals, the Penn State results showed that 39 percent of the respondents planned to hire the same number of nuclear engineers as they had in the past, 6 percent planned to hire more, 12 percent less, and 20 percent for attrition only.

Given the softer demand picture portrayed by the data, Witzig still urges prospective majors to come on board. "I simply give them the figures and tell them, 'if you want to get a job, just be superior.' "

Quality versus Quantity

But numbers don't tell the whole story, emphasizes North Carolina State's Dr. Paul Turinsky, head of the nuclear engineering department there and also chairman of the nationwide nuclear engineering department heads group. He fears industry will not find the superior student referred to by Witzig and will suffer from lack of quality in the long run.

"Nuclear engineering at N.C. State 10 years ago used to attract the best students. We were the glamour area. But we don't see many of the superstars anymore," he said.

Turinsky agrees that graduates will have to look a little harder for jobs this year, but cautions that even one or two years of lean demand will hurt the enrollment picture immensely. Students today are concerned more about employment prospects for the year in which they will enter the job market, rather than promises of a revitalized industry over the long term, he observed. "The future is a harder argument to sell."

By comparison, anxiety about the future threatens to spur an exodus of young engineers already working in the industry, particularly in the aftermath of unfavorable events, said Turinsky. Those with good mobility—engineers with non-nuclear degrees, women or minorities—tend to leave for positions with non-

Enrollment Curricula

Industry Lags In Assuring Staff For Its Future: Palladino

From his vantage point as regulator and former educator, Nuclear Regulatory Commission Chairman Nunzio Palladino shares the concern over the availability of qualified nuclear engineers to meet future demand. Industry, particularly the operating end of it, simply has not come to grips with assuring adequate staff to man all of the positions that will develop over the next decade, he told Nuclear Industry.

"Industry has to put out the message that there are challenging opportunities, that there are vacancies to be filled, and that these are going to go far into the future," he said.

This reflects a growing sentiment among nuclear educators that academia and industry must sit down together and coordinate a strategy not only to bolster enrollment in all nuclear-related programs, but to develop curricula which respond to changing needs.

Industry, Academia Join Forces

An example of such a joint effort, according to Palladino, can be found in Penn State University's two-year nuclear program, which was near death in 1979 until word was put out to local utilities. They responded by embarking on a promotional campaign through articles, ads in local newspapers and scholarship funds. Palladino and others believe just such a concerted effort will be needed in the coming years.

As dean of engineering at Penn State until 1981, Palladino also acknowledged that he, like many of his counterparts nationwide, was forced to cut nuclear resources when faced with a shrinking student body. And as nuclear programs shrink because of low enrollment, teachers either leave or adapt to other disciplines.

Needed: Infusion of Youth

"Nuclear departm[illegible] relatively health[illegible] today are those staffed by peop[illegible] who grew as the industry grew, [illegible]. "But eventually we all get [illegible] we need new generations to [illegible]." For this reason, Pallad[illegible] enough the need [illegible] nuclear engineeri[illegible] at the masters and doctor[illegible] levels, both to assure continued research and to guarantee a steady flow of teachers.

But what will pique a student's interest in nuclear engineering? Simply stated: "The job opportunities and the problems you have to work with." The last month of bad news is minor, said Palladino, considering that the United States has 82 licensed plants and over 50 still under construction.

"The challenges don't cease when the plant is constructed. As a matter of fact, they often begin and get more interesting as the plant gets into operation."

—T.A.N.

nuclear companies at such times.

As the number of nuclear engineering students dwindles and other disciplines experience burgeoning growth, skepticism within academia also is heightened that industry will return to a hiring practice used to fill its ranks during the early years—that of drawing upon those with mechanical, electrical or chemical backgrounds and providing on-the-job training in nuclear.

Need for Nuclear Curriculum

Dr. Carl Erdman, head of Texas A & M's nuclear engineering faculty, warns that industry will require a great deal more management capability than it now possesses if it is forced to rely primarily on engineers not educated specifically in nuclear. He and others acknowledge that a mix of disciplines is desirable and that some things can be learned with experience. But there is a great need for training in areas unique only to a nuclear curriculum, such as fuel management or systems concepts. Industry must not get into a "fossil mentality," they warn, hiring engineers who know the basics but must learn a few "incidentals."

"Thirty years ago, we didn't have a high-tech, high-specialty society associated with probabilistic risk assessment, with the level of safety analysis and environmental protection required, or with source term conditions," stressed Penn State's Witzig. "We had a favorable, supportive environment 30 years ago. It is a myth of old men who think the old way is the way to do it."

The number of nuclear engineering students compared to those in the other fields also makes it difficult for department heads to justify their existence, forcing them to spend greater amounts of time on budget negotiations and prompting many universities to curtail their nuclear programs.

According to figures compiled by the Scientific Manpower Commission, for example, there were 2,168 students enrolled in nuclear engineering programs across the nation in the fall of 1981. By contrast, there were 86,146 electrical engineering students, an area projected to experience the greatest expansion in the coming years; 69,608 mechanicals; 34,661 chemicals; and 44,404 civil engineering majors. Given these numbers, deans of engineering are hard-pressed to be sympathetic to nuclear when allocating scarce resources among all the fields.

DOE Placement Figures For 1982 Graduates

	% BS	% MS	% Ph.D.
Nuclear Utility	24	17	5
Industrial Employment	26	23	23
Foreign Employment	2	5	16
GOCO (Government-owned, Consultant-operated)	1	4	12
Further Study	21	30	2
U.S. Academic	.2	1	15
Other*	16	11	13
Unknown	10	9	14

FEWER ADVANCED-DEGREE GRADUATES entered utility employment in 1982 than entry-level persons with bachelor degrees. DOE also reported that more graduates went to industry than in recent years. "Other" means persons in the military or in state and local government, or seeking jobs.

The Programs Dwindle

As of 1982, there were 62 schools which awarded degrees in nuclear engineering, according to DOE statistics, although only 62 percent of the degrees granted and 63 percent of enrollments were from specifically designated nuclear engineering programs. Of these, 28 were recognized by the Accreditation Board of Engineers and Technicians, a group responsible for quality control in engineering education.

Since 1972, however, 15 programs have been discontinued, five remain on the inactive list, and a handful of others is on the verge of extinction.

When a department is eliminated or merged at the graduate level, commented Turinsky, students tend to move to other universities with separate nuclear programs, thus consolidating and making stronger the surviving departments. But undergraduates, for the most part, are lost when the programs die. They are not as committed at this point and not as likely to relocate.

"Unless you have the identity of being a separate nuclear engineering department, you don't attract the students particularly at the graduate level," he concluded.

Scholarships, Grants Shrink

The availability of scholarships and grants is a crucial element in drawing majors to the field and maintaining solid departments, particularly since such efforts demonstrate industry's early commitment to the student. But in recent years, the level of support from various sectors has dropped, notably from individual utilities which contribute to various schools within their geographic regions.

Industry now funnels much of its support through INPO, which launched in 1980 a series of scholarships and fellowships supported by its member utilities, and has allotted $604,000 for the 1983-1984 academic year. This will include undergraduate awards of $1,500 each to 100 seniors, 50 juniors, 30 sophomores and 20 freshmen. In addition, fellowships of $8,000 each will go to 38 advanced engineering students.

ANS, in addition to various monetary awards for academic achievement or excellence in education, also administers a fund to undergraduate students having greater-than-average needs and definite plans for nuclear careers. The Nuclear Engineering Education for the Disadvantaged (NEED) program currently is seeking applicants and will announce this spring the granting of an indefinite number of $1,500 awards.

ANS Promotes Cure

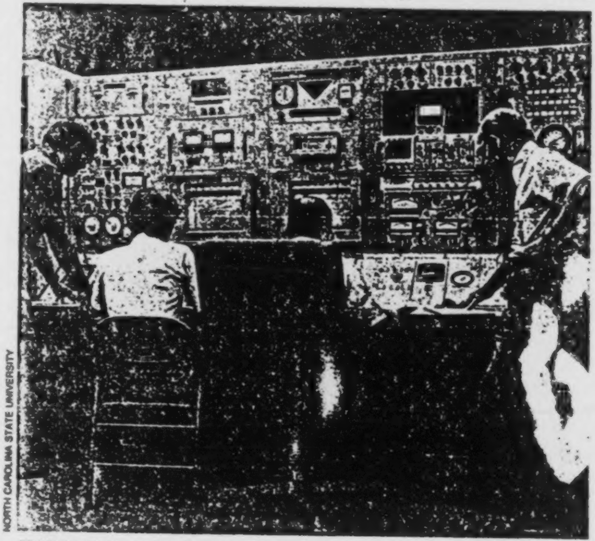
ANS also is in the process of soliciting funds to be distributed this fall to 25 or 30 colleges for use in recruiting at the high school level, an area many feel has been neglected. The College Undergraduate Recruitment Effort (CURE) commenced last summer after an ANS survey showing a need for such assistance, but to date has collected only about a third of its target amount.

At the Federal level, DOE sponsors the Magnetic Fusion Energy Technology and the Nuclear Science and Engineering Fellowships, but support from this sector has dropped markedly in recent years, particularly in the area of fission research. As DOE's research goals become more mission-oriented and geared toward commercially viable projects, it will become even harder for universities to obtain funds for long-term research.

In light of overall enrollment and employment statistics, the negative publicity and the uncertainty surrounding the industry, the perception of need still exists for high-quality nuclear engineers.

"Over the long run, even with pessimistic assumptions, it looks like the job opportunities are going to be there," said Turinsky. "The thing I cannot assure prospective students is that it will be fun. Because the environment is one of hostile regulation, where the average person on the street opposes what you're doing professionally, where we're not building any new plants or engineering new designs, just doing patches and retrofits on existing plants. And that's a shame."

—Teresa A. Nichols



NORTH CAROLINA STATE UNIVERSITY

SENIOR N.C. STATE STUDENTS TRAIN ON UNIVERSITY'S REACTOR

Refinement of Light Water Design Goals:

A Plan for Action

Michael W. Golay

October 1983

Department of Nuclear Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Refinement of Light Water Reactor Design Goals:
A Plan for Action

by

Michael W. Golay

Project Director

of

Department of Nuclear Engineering

Massachusetts Institute of Technology

Cambridge, Massachusetts 02139

October 31, 1983

Executive Summary

A major effort is underway within the MIT Engineering School focussed upon the contributions which technology innovation can make in the revitalization of nuclear power in the United States. A principal component of this effort is a project to refine the design goals of the next generation of Light Water Reactors, with emphasis upon achieving improvements in capacity factor and reduction of the construction duration.

The motivation of this overall effort is to prevent the nuclear option from being lost unnecessarily through being available only in uneconomic configurations. In considering how to advance this effort we have focussed upon refinement of the designs of new reactors because this is the area where the greatest opportunities for improvements exist. It is also the area where the greatest contributions could be made by the group at MIT which would be involved in this project. We have not focussed our project upon improvements in existing nuclear power stations because substantial resources are being devoted to this area currently, because our efforts would not be likely to change significantly the improvements which will be achieved and because the range of possible design modifications in this area is limited. However, we recognize that these improvements will also be valuable to the current generation of power stations.

We have concluded (with perfect hindsight) that in addition to non-technical factors many of the problems of the current generation of power stations could have been prevented through use of a more comprehensively formulated design goal. Such a formulation would involve identifying the attributes necessary for maximizing the economic performance of the plant. It would involve roughly uniform reconsideration of the functions of all portions of the plant, in contrast to the current pattern of a decreasing devotion to design resources as one moves out from the reactor core. We intend to use the experience of the current generation of plants to improve the designs of the next generation. The major technical areas of potential improvements involve simplification, reliability improvements, refinement of safety requirements and design for rapid construction, maintenance and repair.

With the hope that an independent and creative design group centered at MIT could serve as a catalyst for the nuclear industry in advancing such improvements we propose a project - centered at MIT but involving a consortium of leading nuclear utilities - which would refine the design goal which the next generation of LWRs would satisfy. In doing this the complete set of essential performance requirements of these plants would be stated explicitly, in a practical form, and with sufficient supporting analyses to demonstrate that at least one solution for meeting each requirement would exist. The design goal is the statement of the performance attributes desired in the plant, and is distinguished from the plant design specification. The design specification consists of the detailed instructions to potential project bidders for supply of systems and components. The design specification is based upon the design goal but carries it to a much finer level of detail, and includes much additional material. The translation of the design goal to a project specification and its satisfaction by plant project designers would remain beyond the scope of this project.

As envisioned the project would have a total duration of five years, divided into three phases:

1. The project definition phase (one year) - consisting of work upon a small set of high priority projects (see Table ES-1) and a survey of the important operational problems of LWRs worldwide.
2. The preliminary design goal definition phase (two years) - consisting of individual investigations for practical formulation of a preliminary design goal.
3. The final design goal definition phase (two years) - consisting of transmittal of the preliminary design goal to the consortium utilities, with further investigations completing and refining the design goal statement, incorporating the utility feedback.

The project would involve between four and eight utility organizations. Each utility would be asked to contribute two staff members to work at MIT, the oversight involvement of a Vice President and the financial support for two MIT investigators plus associated graduate students. The project director would be Prof. Michael W. Golay of the MIT Nuclear Engineering Department. The project members would guide the evolution of the design goal collectively. Based upon the results of individual project investigations they would periodically revise the goal and the direction of future investigations in the project. The initial generation of investigations would be concerned substantially with distillation of the lessons of the experience of plants in the United States, Europe and Japan. Based upon the preponderance of current and likely future LWR plants the initial project focus will be upon PWR innovation.

Finally, it has been suggested that the proposed work is unlikely to be important if the currently hostile political and incoherent regulatory environments do not become more sympathetic and predictable. Rather, efforts to improve the prospects for nuclear power would best be devoted to these socio-political areas. To the contrary, we expect that nuclear power will continue to have political opposition and a difficult regulatory environment until it becomes so reliable and uninteresting to the public that substantial anti-nuclear-power constituencies will no longer be sustained. If so, the proposed project will serve the advancement of both the economic and public acceptance of nuclear power. We hope that others will share this view, and our enthusiasm for the proposed project's success.

Table ES-1

Specific Efforts Which Could Be Undertaken During the First Year of the Project

- Investigation of the most important applications of advanced signal transmission and information processing technologies
- Assessment of possible improvements in pump reliability
- Assessment of simplification and improvement of secondary water chemical treatment
- Development of reliability-oriented PRA to assess design tradeoffs in plant simplification - elimination of the PWR soluble boron system as a trial example
- Refinement of the design basis earthquake specification and of regulatory requirements for its survival
- Refinement of regulatory requirements for fire mitigation

Table ES-2

Major Points of Executive Summary

Project Goals

- Refinement of comprehensive statement of LWR design goals
- Statement of such goals in practical form
- Substantiation of goal feasibility by at least one demonstrated solution

Project Information Resources

- Experience base of current LWR plants (United States and foreign)
- Detailed experiences and judgments of member utilities
- Expertise available at MIT
- Other worldwide nuclear industry organizations which may be recruited for project as needed

Project Staff

- Utility staff members working at MIT
- MIT investigators (professors and graduate students)
- Project coordination at MIT

Project Organization

- Location and direction at MIT
- Personnel, management and financial support by participating utilities
- Semiannual meetings for project evaluation and redirection
- Five year total project duration
    - One year project definition stage
    - Two year preliminary design goal formulation stage
    - Two year final design goal refinement stage

FREDERICK L. WEBBER, Executive Vice President

EDISON ELECTRIC INSTITUTE The association of electric companies

1111 19th Street, N.W.
Washington, D.C. 20036
Tel: (202) 828-7400

April 4, 1984

The Honorable Marilyn Lloyd, Chairman
Subcommittee on Energy Research and Production
Committee on Science and Technology
Room B-374 Rayburn House Office Building
Washington, DC 20515

Dear Madam Chairman:

Enclosed are our responses to questions contained in your letter of March 20.

We stand ready to assist you should you need additional information.

Best personal regards.

Sincerely yours,

Frederick L. Webber

FLW:fdg
Enclosure

RESPONSE TO CHAIRMAN LLOYD'S QUESTIONS ON NUCLEAR FISSION R&D

1. In your summary of the nuclear industry today, you asked the question "what more could we ask for?" There seems to be a lack of leadership in the industry. There also appears to be a low degree of confidence today, both among utilities and the general public. There certainly is a lack of orders for new facilities. To what extent can these conditions be improved by changes in licensing and regulation?

The uncertainty of the licensing process is vividly illustrated by the inability of the Nuclear Regulatory Commission to make a timely decision on the operation of Diablo Canyon nuclear power plant. Such uncertainties are a primary cause of plant delays and large cost overruns with completed nuclear plants being held hostage to the process. Improvements in the regulatory process must be achieved before the nuclear option will be called upon for future plants. The licensing process must permit one-step licensing, a rationalized hearing process, encouragement for standard plant designs, early site approval, and a uniform basis for determining the need to incorporate backfits.

2. It seems quite apparent that the nuclear industry, among its many participants, must change something. A recent suggestion is that small, modular, standardized units be offered. What barriers do you see to such a proposal?

Small, modular, standardized nuclear units are a fad of the present time as one approach by some DOE contractors to seek out a product that might be acceptable. There is little enthusiasm for any form or type of nuclear plants at this time by the electric utilities for several reasons with one very important reason being that the regulatory process is unpredictable. This is a fact that is even more applicable to a new reactor concept than to an existing commercial concept. The small, modular, standardized unit concept is viewed by some to overcome the unpredictability of the process, and this is in doubt. Only after full development, license approval, demonstration and an assured economic basis, will any new concept be attractive to the electric utility industry.

Since tens of billions of dollars have been spent on light water reactor (LWR) technology and several billions of dollars spent on liquid metal fast breeder reactor (LMFBR) technology, these are the only two concepts that appear to have a reasonably dependable existing basis for future use. All other concepts are at a major disadvantage because of the lack of a substantial experience and knowledge base. Before any new concept could achieve commercial acceptability, billions of dollars of expenditure would be required to demonstrate its applicability. Since the utility industry and its electricity customers will be unable to commit such funding, the practical ability to reach commercialization is very much in doubt for any new concept, including a small, modular, standardized unit that uses any technology other than LWR or LMFBR.

27
Hrg.

WESTINGHOUSE HANFORD COMPANY, RICHLAND WA 99352

OMNIFAX TELECOPIER

FTS - 444-4746
COMMERCIAL - (509) 376-4746

VERIFICATION

FTS - 444-3347
COMMERCIAL - (509) 376-3347

DATE: 3/27/84
FAX: 225-3292
VERIFY: 225-3271

TO: Via Cong. Marilyn Lloyd's Office for transmittal to
NAME • LOCATION
the attention of Ms. Debbie Martin, Subcommittee Office,
Room B-374 Rayburn House Office Building
Washington, D.C. 20515

FROM: E. A. Evans Westinghouse Hanford Company
NAME LOCATION

833-5026

THIS TRANSMITTAL CONSISTS OF 4 PAGE(S), "EXCLUDING COVER SHEET"...

TIME SENT: ____________

VER. BY: ____________

1. How does US fuel cycle technology compare with that of the rest of the world, both the Western and Communist (Russian) bloc countries?

   The US is well ahead of other countries in its overall laboratory, industry and utility experience in fuel design, fabrication, and irradiation. This is true of both the amount of ceramic fuel irradiated and the quality of irradiation data on both cladding and fuel materials. US fuel cycle technology complements rather than competes with that of both the Western and Communist (Russian) bloc countries. France, England, and Russia have operated large (to 600 MWe) breeders for years. However, none of them now operate significant fuels and materials test reactors such as EBR-II, FFTF and JOYO (Japan). They do obtain experience in routinely operating large power production reactors, sometimes with large numbers of failed fuel elements. The Russian breeders use enriched uranium fuel, which is not at all economic. The USSR and others irradiate large amounts of relatively big assemblies, but none approach the realistically anticipated US goals for several-fold increase in fuel and control assembly lifetimes. This is important for not only the several-fold decrease in fuel fabrication and reprocessing but also for reliable (uninterrupted) reactor operations. In the commercial reprocessing part of the fuel cycle, US hopes depend upon ORNL studies, Barnwell and the Breeder Reprocessing Engineering Test (BRET) of ORNL and HEDL.

2. To be supplied at a later time.

3. To be supplied at a later time.

4. Do you believe that small reprocessing facilities, closely coupled to one or two breeder powerplants, can be economically justified?

Small reprocessing facilities, coupled to one or two power plants, probably are economic only for small special purpose "grids", such as those associated with a remote military installation, or special applications. In general, breeders should be associated with relatively large grid requirements to be economically justifiable. France and others are planning small experimental facilities to learn how to optimize breeder fuel reprocessing but, except for very special applications, it would be difficult to imagine economic competition with immense, upgraded facilities such as the LaHague reprocessing plant, with all the additional upgraded capacity now being designed and constructed.

5. To minimize the capital investment associated with the breeder and its fuel cycle, what do you believe might be the optimum total power produced by breeder reactors that would be compatible with one reprocessing and fuel fabrication plant on one site?

Up to a dozen or more breeders could be built on an appropriate site with a large associated electrical power grid to be serviced by one reprocessing plant and one fabrication facility. This would optimize transportation, waste handling, and technical support, as well as capital costs. The political, social, and other problems obviously might be serious, as well as the number of candidate sites. Obviously, the timing for such proposals is some decades in the future.

6. In parallel with current fuel cycle activities, might it be appropriate to explore the potential for reprocessing with a dry process such as plasma separation?

Technology for a dry process such as plasma separation to be economic for reprocessing seems far off. This conclusion could change with further success in current isotope separation programs, but competition with the "moving target" presented by integrated facilities such as LaHague and Marcoule makes it seem unlikely.

7. Are there ways that facility operating costs at Hanford for breeder technology can be reduced without seriously impacting programmatic efforts?

Facility operating costs are under review. There have been major personnel reductions and other streamlining efforts at HEDL. Further cost reductions might be possible by further major consolidation of certain operations, provided up-front resources were available.

8. What is the status of France's fuel cycle technology in comparison to ours?

France's basic fuel cycle technology involves a relatively small effort compared to the US, but the people are equally competent and they have moved ahead to essentially a world monopoly on commercial fuel reprocessing. Recently observed capabilities at LaHague, such as those for plutonium oxide processing, reveal inspiring ingenuity and know-how. Progress in waste solidification, including new facilities under construction, also is most impressive. The fuels technology was strongly supported by RAPSODIE (now shut down) and PHENIX. The operating experience in PHENIX, and, hopefully, the SUPER PHENIX reactors will be important, but severely limited. To develop long-lived fuel which will reduce reprocessing and fuel fabrication costs, while achieving safe, reliable reactor operations, the complementary US program, with the EBR-II and FFTF, is indispensable. Expanding on this, large breeder plants have long been operating in France, UK, and Russia, and the supporting facilities have been built and are being expanded, with closer integration among countries such as the recent UK-European agreements. From this complex, plutonium is becoming available which in some cases will be put to less than optimum use for applications which are less than desirable. International efforts which complement rather than compete with each other should be strengthened quickly for both economics and security reasons.

9. Please provide for the record your views on the pros and cons, advantages and disadvantages, of the oxide fuel cycle as compared to a metal fuel cycle of the type proposed for the EBR-2.

The metal fuel cycle was demonstrated on a small scale at the EBR-II site many years ago with driver fuel which was enriched with U235. This would not be economic for breeder plants for large commercial electric power grids. Much depends upon development of plutonium alloys which are still under investigation and have been irradiated on a very small scale. However, oxide fuels have what the majority of fuel and reactor experts believe are inherent, demonstrated safety and economic advantages supported by worldwide efforts involving literally billions of irradiated ceramic fuel pellets. The supporting technologies of reprocessing, materials studies, and so forth, are also much better established worldwide for the ceramic fuels. Possibly for small, special purpose reactors, and for irradiation testing in general, overall EBR-II capabilities continue to be very important. The EBR-II itself has operated remarkably well for decades, including an impressive production of electric power while enduring the "insults" of imaginative, aggressive US fuel testing programs.

10. Please give the Committee your views on the possibility of improving upon the PUREX reprocessing method as it relates to commercial fuels; for example, are there approaches to reprocessing, such as plasma separation techniques, that merit further R&D investigation?

Improved and possibly different processes and equipment are desirable for breeder reactor fuels which have relatively high enrichment, long lifetimes. Evolution from wet processing methods based on PUREX, ORNL studies, France, and progress in other countries would seem to be the most likely evolution of really economic, reliable and safe reprocessing. This involves a high research content and continuity of effort such as that illustrated at the LaHague site of France.

11. Does your use of the term "the inherent safety characteristics" of the FFTF refer to safety by design or to safety by the nature of the process?

In reference to the term "inherent safety characteristics" of the FFTF, I refer to the physical processes which are intrinsic to the reactor plant as it has been designed and built. The physical processes exist by nature, but their effectiveness as safety characteristics depend upon careful design. The consideration and use of such inherent safety characteristics was an integral part of the FFTF design from the beginning. Some of the specific inherent safety features of the FFTF are:

- Low pressure heat transport system.
- Prompt negative fuel temperature coefficient of reactivity (Doppler).
- Natural circulation shut-down heat removal (inherent passive emergency core cooling).
- Limited possible coolant loss in event of a system leak, assuring continuity of core cooling.
- Multiple coolant flow passages to fuel bundles assuring against flow blockage by a foreign body.
- Series wiring of primary pumps and safety rod power, assuring reactor shutdown without safety system action in case of loss of pumping power.
- Thermodynamic compatibility of oxide fuel and sodium, assuring that even molten fuel contact with sodium would not produce energetic interactions.
- Chemical compatibility of coolant, cladding, and fuel, assuring impossibility of energetic or gas-generating chemical reactions.

In conjunction with the application of inherent safety characteristics, the FFTF is also engineered to limit the possibilities and probabilities of serious malfunctions, to assure safety system actions to limit the consequences of malfunctions, and to provide additional safety margins for unforeseen or hypothetical accidents.

12. How long do you anticipate the operation of the FFTF to conclude its essential mission? At what total cost?

FFTF was designed for a minimal 20 year operating life, to cover the testing of the cumulative lifetime(s) of initial and advanced components. The total cost is a function of the complexity of its program, which has yet to be fully detailed, especially in its later years.

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
NUCLEAR DIVISION
POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37830

March 2ˉ,

MAR 27 1984

Congresswoman Marilyn Lloyd
Chairman, Subcommittee on
Energy Research & Production
Committee on Science and Technology
U.S. House of Representatives
B374 Rayburn House Office Building
Washington, D.C. 20515

Dear Congresswoman Lloyd:

I am pleased to submit answers to your questions additional to the testimony, "Statement on The Consolidated Fuel Reprocessing Program," presented before the Subcommittee on Energy Research & Production Hearings on February 7, 1984.

Sincerely,

Donald B. Trauger
Associate Director for Nuclear
and Engineering Technologies

DBT:bdb

Enclosure

ANSWERS TO

ADDITIONAL QUESTIONS FOR TESTIMONY

ON STATEMENT

THE CONSOLIDATED FUEL REPROCESSING PROGRAM

of February 7, 1984

by

D. B. TRAUGER
ASSOCIATE DIRECTOR
NUCLEAR AND ENGINEERING TECHNOLOGIES
OAK RIDGE NATIONAL LABORATORY*

For The

SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY
MARILYN LLOYD, CHAIRMAN

March 23, 1984

*Operated By Union Carbide Corporation
for the
U.S. Department of Energy
Under Contract W-7405-eng-26

March 23, 1984

ADDITIONAL QUESTIONS FOR
DONALD B. TRAUGER

1. **Do you believe that small reprocessing facilities closely coupled to one or two breeder power plants can be economically justified?**

2. **Is it technically and economically feasible to design and operate a small breeder fuel cycle that would service a single reactor only? This could permit employing a totally closed nuclear steam supply system that could be marketed as a single package including the fuel cycle.**

3. **With the successful demonstration of remote control and manipulation devices at the Oak Ridge Integrated Equipment Test Facility, why is construction and operation of the breeder reactor engineering test facility necessary for similar demonstration at Hanford, Washington?**

4. **It would appear that the continued operation of the PUREX in Hanford does not necessitate the demonstration of the process at the BRET facility. Please comment.**

I will respond to Questions 1 and 2 together and then address Questions 3 and 4 separately.

Earlier evaluation of scaling factors for fuel reprocessing lead to the conclusion that only large-scale plants would be economical. Since only preconceptual designs have been prepared for any fuel reprocessing plant using fully modern technology such as proposed for the Breeder Reprocessing Engineering Test (BRET), it is not possible to provide current cost information. However, the effect of new technology on scaling factors can be answered in general terms. I will attempt to address these and other factors which relate to the coupling of reprocessing facilities to power plants.

An important consideration in the close coupling of reactors and other fuel cycle activities is the added complexity for the utility company. In order to reprocess on site, either the utility must add very extensive chemical engineering capability including the handling of high level radioactive waste, or the site would be shared by two or more operators. Either approach introduces major new management problems. It appears unlikely that close coupling of reprocessing to reactors can be made attractive to the industry unless the larger power park concept is employed. However, several factors which may influence such decisions are discussed herein.

The Consolidated Fuel Reprocessing Program (CFRP) including both BRET and the supporting test facilities and equipment, particularly the Integrated Equipment Test (IET), will provide a base of technology for improved fuel reprocessing regardless of plant size or application. These test facilities have as important goals: greatly improved operation, reduced cost, better safety, reduction of worker exposure to radiation, improved safeguards, minimal environmental impact, and applicability to proliferation control systems.

BRET to be located in an existing facility on the Hanford reservation would provide a sound base of experience for estimating the cost of future commercial plants while closing the fuel cycle for the Fast Flux Test Facility (FFTF). The design allows for relatively easy replacement or modification of equipment so that newly developed concepts can be incorporated at any time. It can reprocess fuel from the FFTF in essentially a one-on-one closed cycle system when operated in conjunction with the Secure Automated Fabrication (SAF) facility. For test purposes, small quantities of LWR fuel might be used to supplement that available from FFTF.

The design objective of the CFRP has been to develop more efficient operation, improved components, and replaceable equipment. It is anticipated that these features can favor smaller plants with attendant lower capital costs, but new scaling factors cannot yet be determined. This development also should make it possible to extend the lifetime of reprocessing plants to essentially indefinite operation. The cost could be amortized over a longer period of time possibly facilitating smaller reprocessing units if they prove to be desirable.

An integral fuel processing and refabrication plant was operated for several years in conjunction with the Experimental Breeder Reactor (EBR-2) test facility. This operation was based on metal fuel rather than the mixed oxide fuel used for essentially all other fast breeder reactors in the United States and abroad. Extensive analysis during the Nonproliferation Alternative Systems Assessment Program (NASAP) and International Nuclear Fuel Cycle Evaluation (INFCE) studies showed this to be less competitive than the oxide system. However, recent developments at the Los Alamos and Argonne National Laboratories show promise for improved performance and cost. Key elements of these developments have been tested only at a small bench scale level. They are deserving of further study and development, but it seems premature to concentrate on this system until further tests have been completed and designs have been developed which are adequate for estimating costs. It is particularly important to note that the remote handling systems of BRET and IET, which are the key elements of the CFRP, are applicable to metal fuel systems and in fact would be required.

Based on the similarity between the fuel recycle planned for FFTF (BRET and the SAF line) and what would be required for a fuel recycle capability coupled to a commercial reactor, we would expect the fuel recycle facilities to cost between twenty-five and fifty percent of the cost of a single reactor. The facilties would cost only slightly more for a two or three station complex so that fuel recycle costs would be relatively less. However, they would remain substantially higher than for larger centralized facilities. Total fuel recycle costs for an outside fuel recycle for a single reactor station are expected to be three to five times that for central facilities, with most of the extra costs associated with reprocessing.

In comparing small integral reprocessing plants with larger central facilities, we note that safeguarding may be equally effective in either. The remote features of the CFRP and SAF developments provide means to prevent direct access to the fuel by the operators for any size plant. Shipment of reprocessed fuel is fully accountable, thus safeguarding can be complete. However, central facilities may be more amenable to monitoring for protection against proliferation. The multitude of separate reprocessing facilities if utilized in a large power system would present problems of acceptance. The large number of inspectors required would represent a substantial cost and perhaps problems with acceptance for adequate monitoring. Thus the larger scale plant appears to have advantages both economically (economy of scale) and for proliferation resistance. Fuel reprocessing also reduces the long term storage costs and the attendant problems which are associated with that mode of fuel handling. Obviously, if breeder reactors were to provide fuel for new units, fuel shipment would be required.

In response to question three, the IET at ORNL is a test facility designed to develop, in a non-radioactive environment, the components and remote maintenance techniques needed for BRET. It provides an essential step preliminary to demonstration of the technology in BRET with actual spent fuel in a highly radioactive environment. It also can accommodate larger components than those which are required or can be used in BRET. The two facilities are complementary and together should provide an adequate base of experience for the design of a fully modern reprocessing plant. The technology can be applied to both commercial and new production reactor reprocessing plants.

With respect to the fourth question, the existing PUREX plant was designed and constructed with the technology of thirty years ago for very large throughput with low burn-up production reactor fuel. It was operated successfully, has been restored after long idleness to its original state, and is being used to recover plutonium from spent "N" reactor fuel using the head-end chemical dissolution step. This process is not feasible for either LWR or LMFBR fuel.

The proposed addition to PUREX would provide a head-end step for shearing and dissolving FFTF fuel. The original solvent extraction plant would be used by diluting the plutonium with uranium. While the plutonium can be recovered in this manner, this modification would not develop the technology needed for a commercial breeder fuel cycle nor address licensing issues for commercial plants which are goals of BRET. Furthermore, since this is a defense facility, international collaboration including safeguards and non-proliferation related to facilities would be restricted to IET. Also, U.S. utilities may not consider this to be an adequate demonstration of breeder fuel cycle technology.

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
NUCLEAR DIVISION

POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37830

APR 09 1984

March 30, 1984

Congresswoman Marilyn Lloyd
Chairman, Subcommittee on
Energy Research & Production
Committee on Science and Technology
U.S. House of Representatives
B374 Rayburn House Office Building
Washington, D.C. 20515

Dear Congresswoman Lloyd:

You asked for responses to some additional questions relative to your Subcommittee hearing on the Department of Energy's budget request for Fiscal Year 1985. These are given below.

(1) Would you explain reactor power density to us and what that has to do with inherent safety?

Reactor power density is a measure of power generation per unit volume (such as kW(t)/liter), and generally refers to the average value in the active core region of the reactor. Reactor power density is related to inherent safety insofar as low power density leads to a reduced rate of coolant heatup subsequent to loss of core cooling. Systems with inherent safety refer to those systems such that during and following extreme accident conditions the fuel will not fail in a significant way because of passive safety features; that is, fission products will not be released from the reactor circuit in significant amounts. To keep the fuel elements from failing in a massive way during extreme accident conditions, it is necessary to store and transfer energy without excessive fuel temperatures. The maximum fuel temperature attained is determined by both the energy generation rate, the heat capacity of the system, and the energy dissipation rate. The slower the temperature rise in a reactor core, the greater will be the ability to dissipate energy from the core to other passive heat removal systems. Thus, a low core power density leads to lower fuel temperatures in a given time during and following loss of cooling accidents, and leads to having more time to dissipate energy to passive heat removal systems. These factors help limit the maximum fuel temperature. Other factors which improve inherent safety include high unit heat capacity of the fuel and coolant, high temperature capability of the fuel and coolant, and high heat transfer from the core to a passive heat removal system.

The second (Minority Questions) series of questions cover the following.

(1) Please define the term "inherently safe."

The term "inherently safe" as it has been used in the hearings refers to a reactor system where fuel cladding integrity and fission product retention depends largely on passive safety systems rather than on active safety systems (such as injection pumps or auxiliary heat exchanger circuits). The term "inherently safe" is a misnomer in a certain sense since engineered safeguards (such as a reactor vessel) are utilized in all concepts. A better term would be the use of the term "reactors with improved passive safety features." Such reactors, when exposed to extreme accident conditions, neither lead to conditions which challenge the integrity of the reactor vessel, nor to significant fission product release from the fuel or from the reactor circuit. Reactor systems with such behavior would provide assurance of high public safety and high investment safety. The attainment of such behavior in practical reactor systems will need significant effort.

(2) Your testimony continually refers to inherent safety only regarding the High Temperature Gas-Cooled Reactor process. Why do you omit other nuclear processes such as the breeder, LWR, or BWR?

My testimony primarily addressed the High-Temperature Gas-Cooled Reactor since I am intimately familiar with that reactor concept. Other people addressed new designs for breeders, LWRs or BWRs which have improved passive safety features. The fact that I emphasized high-temperature reactors (HTRs) does not imply that other reactors cannot be designed with passive safety features. HTRs do have certain inherent and unique features which are attractive to achieving improved passive safety. At the same time, there is need to investigate economic and safety performances of all the reactors mentioned, evaluating them on consistent, technical bases.

(3) Please comment on the PIUS reactor concept.

The PIUS reactor concept is one which provides a large heat capacity by means of a large volume of relatively-cool water which surrounds the core. Following a loss of cooling accident, the relatively-cool water (which contains large amounts of boron) will enter the core region because of natural-convective-flow forces. The boron in the entering water keeps the reactor subcritical, while cooling of the core is provided by the entering cool water. The proposed design provides sufficient cool water such that fuel failures or excessive pressures or temperatures in the system do not occur for many days. The safety design concept is unique and clever, and appears to provide the shutdown and cooling capability required to give desired passive safety features. At the same time, it is not clear that the thermal-hydraulic balance which is necessary to keep the boron-containing water separate from the core coolant regions will indeed always be maintained under the transient conditions which occur during normal reactor operations. If boron enters the core frequently, the reactor availability could be significantly reduced, which impacts economic performance. Increasing the resistance to flow between the other regions and the reactor circuit slows the response of boron addition to the core following loss of cooling accident. There is also concern about the ability to perform practical maintenance on components of the reactor circuit without excessive reactor down times. Overall, PIUS is an interesting concept, but significant questions need to be answered to determine its practicality. Research and development is needed in the above indicated areas if the concept is to be developed into a practical system.

Sincerely,

Paul R. Kasten

Paul R. Kasten, Director
Gas-Cooled Reactor Programs

PRK:jh

cc: F. R. Mynatt
D. B. Trauger

TENNESSEE VALLEY AUTHORITY
KNOXVILLE, TENNESSEE 37902

OFFICE OF THE BOARD OF DIRECTORS

June 4, 1984

The Honorable Marilyn Lloyd, Chairman
Subcommittee on Energy Research and Production
U. S. House of Representatives
B-374 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Lloyd:

This is in response to your March 20 letter to George Dilworth requesting our responses to your questions. Our response is later than you had requested; however, Ron Williams of your staff was agreeable to allow more time.

The enclosed response is somewhat general; however, we would be glad to assist in some way in the future in developing more detailed alternatives for integrating a new licensing program with the research, development, and demonstration programs for alternate reactor types.

Sincerely,

CHDean

C. H. Dean, Jr.
Chairman

Enclosure

1. If the government were to initiate a research and development program with the objective of designing and building a modular HTGR, how would you suggest that a new licensing program be established so that the NRC would not be tempted to bend LWR criteria and apply it to a gas reactor?

    The development of more passive reactors should afford the Nation an opportunity to establish an efficient and timely licensing process without sacrifice of "safety first" as a goal.

    Establishment (as a specific regulatory requirement) of an overall level of safety which will adequately protect the public from injury as a result of operation of a nuclear plant is a necessary beginning.

    Another fundamental element in a new licensing program should be a statement of design goals as a subset of the major purpose of preventing injury to the public (and those who work at the plants). For example, a new design goal could state, "Prevent core damage in all conceivable circumstances" or "Prevent fission product releases greater than (some specified amount) under all conceivable plant situations." These examples may appear simplistic, but to adopt these or similar goals requires a major transition in the NRC/industry/public approach to licensing. The question of the level of required safety should be answered acceptably for all parties. Failure to reach this point early in the development process of new reactor types will leave future reactor development subject to a moving target approach which is doomed to failure from the start.

    Another desirable licensing element would be establishment of uniform functional requirements with demonstrable reliability. This would demand extensive testing of plant components and systems and result in survival of fewer customized options available to utilities. To be cost competitive, vendors will narrow their areas of specialty resulting in greater standardization among plants. This has occurred in other countries where some components are only available from two or even one vendor. The product offered must meet stringent requirements and be less susceptible to change through customized utility requests.

2. If a modular HTGR was constructed, would you then advocate full testing under the most severe transient conditions to prove the "walk-away" concept?

    Public opinion about nuclear power appears to be shaped in part by the uncertainties about the capability of the plant (and/or operators) to prevent an accident resulting in large fission product releases. Many intervenors in licensing hearings for LWRs have raised the issue of full scale testing of the emergency core cooling system and other design basis verifications.

The modular approach should allow meaningful research and development and demonstration activities to prove, possibly up to full scale, the performance of the modular loop before any commercial plants are designed and built. It may be possible to test at worst case accident conditions using a fully fueled core. If this isn't practical, the thermal, hydraulic, and passive heat removal performance could be demonstrated in full modular size. This would go a long way toward proving the licensing basis can be met and the modular loop could be certified as a "product licensed for use."

Assuming this modular loop could then be a building block for a plant unit which could consist of a number of these loops, to achieve versatility in unit size, the remaining integrating function for multiloop licensing should be accomplished without full scale multiloop testing.

A decision on the need to test the entire modular loop under the worst accident conditions need not be made immediately. An assessment of this need should be made later to allow time for the design to be well along and determine whether or not such testing is needed for technological or public acceptance purposes or both.

3. Would TVA buy a standardized nuclear reactor, with standardized balance-of-plant equipment? If not, why not? If so, what efforts has TVA made in the past to procure such equipment?

The need for additional capacity on our system and the type of generating option we would purchase necessarily would depend upon economic, safety, and environmental considerations at the time such a decision is made. If we make a decision to buy more nuclear reactors, they would certainly be standardized.

TVA's interest in and support for standardization goes back to 1973. The four Hartsville and two Phipps Bend units were to have been standardized General Electric designs. For these units, the design package scope was called the Reactor Island, and it encompassed a great deal more than the usual nuclear steam supply system. The two Yellow Creek units were to have been Combustion Engineering standard plants. The type of standardization achieved through these designs was probably less than what is perceived as necessary in today's climate. Many utilities, including TVA, are demanding more certainty in their purchasing. To achieve this, it is very likely the industry will return to the "turnkey" concept of the early years of commercial nuclear power.

Although TVA has always performed its own balance-of-plant design and has traditionally exercised a great deal of influence over the nuclear vendors' designs, if we enter the market for new nuclear capacity, I would anticipate less customization of plant design. The complexity of nuclear plant design, construction, and operation has led us to believe standardization and replication will be major components of the revitalized industry.

4. At what rate does TVA presently forecast future electrical growth rate to 2025? Please respond both as percentage growth and in megawatts per year.

TVA Net System
Seasonal Peaks and Growth Rates

	Forecast								
	Low			Medium			High		
FY	Peak MW_e	Average MW_e/Yr	% Per Yr	Peak MW_e	Average MW_e/Yr	% Per Yr	Peak MW_e	Average MW_e/Yr	% Per Yr
1985	19,140	-	-	20,770	-	-	21,806	-	-
2020	24,715	160	0.7	38,217	500	1.8	53,005	890	2.6

P. O. BOX 14000, JUNO BEACH, FL 33408

FPL
FLORIDA POWER & LIGHT COMPANY

March 28, 1984

APR 04 1984

Ms. Marilyn Lloyd, Chairman
Subcommittee on Energy
Research and Production
U. S. House of Representatives
Committee on Science & Technology
Suite 2321 Rayburn House Office Bldg
Washington, D. C. 20515

Dear Ms. Lloyd:

In response to your letter dated March 20, 1984, listed below are the responses to your questions.

--What size plant do you anticipate to be located at the South Dade site, which is approximately 20 miles south of Miami?

Because the cost of capital will probably remain high, we must more closely align our capacity additions to load growth. We predict that our load growth will be approximately 3%/year in the 1990's so we will be looking for 300 MW/year in new capacity plus additional amounts to replace plant retirements. Several thousand megawatts of capacity could eventually be located at the South Dade site in units of approximately 400 MW each.

--If you bought a High Temperature Gas-Cooled Reactor what problems do you anticipate would occur with regulators?

We will not buy an HTGR unless the "problems" with the regulators are ironed out beforehand so that this element of risk is minimized. This means that a demonstration reactor has been built and shown to be "inherently safe" and the design and construction in the factory has been certified by the NRC (much like the FAA does for aircraft).

--What is necessary to sell the "Inherently Safe Reactor" concept to the world?

Build a demonstration reactor and subject it to severe testing to prove it is "inherently safe". The General Electric Company did this at SEFOR (Southwest Experimental Fast Oxide Reactor) where, for the ultimate test, they fired a control rod out of the core putting the reactor on a severe power transient to prove that the doppler coefficient would stop the transient. (It did.)

--Your present company is indeed to be commended for the completion of the nuclear unit St. Lucie Unit 2. What are the 4 or 5 main factors which contributed to this very successful venture?

1. Management Commitment - This is commitment from the Chairman of the Board down to the individual project team member to meet the schedule established in 1977, stay within budget, and "Do it right the first time" to provide a quality job to meet our commitments in the Final Safety Analysis Report.

2. Teamwork - We were blessed with a seasoned project team and the owner was in firm control. This team became large at times. For example, at one point the entire Florida Congressional delegation was involved in convincing the NRC that they should adjust their licensing schedule to match our construction schedule.

3. Engineering well ahead of Construction - Because we continued engineering after we lost our Limited Work Authorization we were able to complete 75% of the original design prior to start of construction.

4. Close coordination with the NRC - We recognized the role the NRC has to play and we were careful not to set up an adversarial relationship. We set up an office in Bethesda and manned it with 3 engineers and a secretary. We were able to answer formally 600 questions in 6 months and thousands of questions informally thus avoiding a blizzard of paper.

When we met with the NRC to obtain our full power license for St. Lucie Unit 2, Chairman Palladino suggested that we publish a little booklet to tell others how we did it. We did this and a copy of this is enclosed for your use.

--What is your impression of the Modular HTGR and how would you feel about purchasing a reactor which was delivered to the project site as four major assemblies, such as the nuclear steam supply system, secondary system, turbine/generator and control room, with the balance of plant constructed on-site?

We feel that the modular HTGR shows promise to reduce the capital costs and exposure to risks and uncertainties. One major way to do this is by factory fabrication of practically the entire plant and factory certification. When we can feel comfortable with quantifying the uncertainties and gain confidence as to the final costs of producing electricity using an HTGR, we will then be in a position to contract for an HTGR plant.

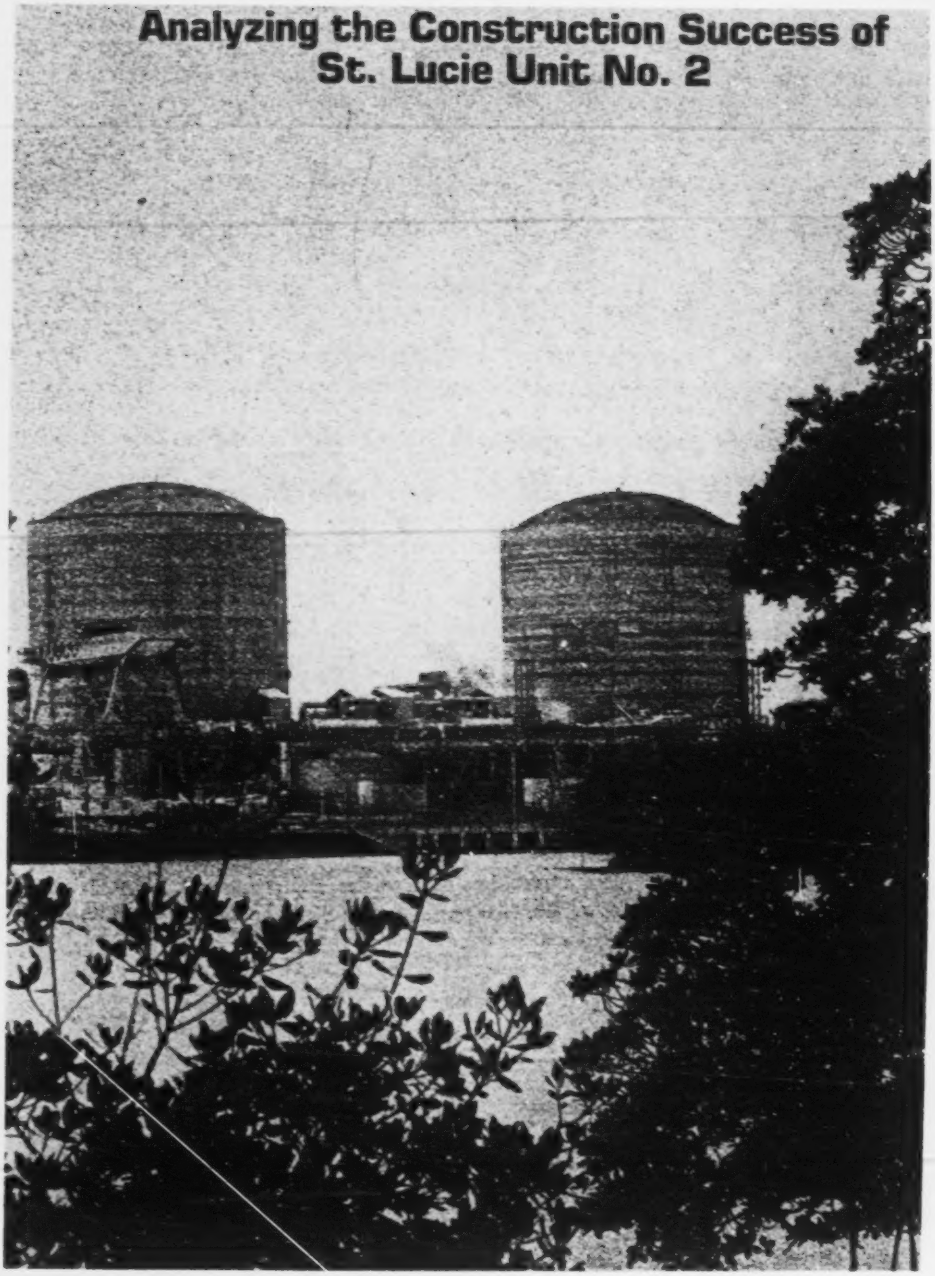
Sincerely,

H. J. Dager
Vice President - Engineering,
Projects, Construction

HJD/mls

Enclosure

Analyzing the Construction Success of St. Lucie Unit No. 2



"In the frustrating world of nuclear construction, the losers get all the attention. If it's not the five construction-quality-assurance failures cited by Nuclear Regulatory Commission Chairman Nunzio Palladino in his Dutch-uncle lecture last year, it's the WPPSS fiasco in Washington State, Three Mile Island, scheduling foul-ups and the embarrassing cost spiral that dominate the headlines.

"But while most nuclear utilities and contractors have been busy explaining their problems, a tightly knit team working on an island off the east coast of Florida has been busy solving theirs. The result at St. Lucie unit two will be completion of Florida Power & Light Co.'s 810-Mw pressurized-water reactor, at a cost of $1.42 billion, in June, exactly six years after its construction permit was issued.

"That's a benchmark in the nuclear construction business these days. By comparison, the lead times for the 10 plants completed since the beginning of 1978 -- one before the Three Mile Island accident in March, 1979, and the rest since 1980 -- have stretched out from 96 to 144 months."

ENGINEERING NEWS-RECORD, April 21, 1983
McGraw-Hill, Inc., Copyright 1983

ANALYZING THE CONSTRUCTION SUCCESS OF
ST. LUCIE UNIT NO. 2

One measure of success in building any power plant is how closely the project adheres to the original schedule. At Florida Power & Light Company's St. Lucie Unit No. 2, construction of the nuclear unit has virtually met every major milestone, logging 59 months between work start and completion of cold hydro, which is 36 months better than the industry average.

Initial criticality was achieved on June 2, and barring unforeseen circumstances, the unit should be placed in commercial operation by mid-summer 1983, only two months -- or 3% -- off the originally targeted date.

The history of the project and the innovations and planning which went into its success are summarized in this paper. The result of that teamwork and dedication are the fuel cost savings of $20 million per month, which will be passed to FPL's 2.4 million customers.

MANAGEMENT COMMITMENT

From the start of the project in 1976, FPL management was committed to provide the necessary resources to meet the project objectives to build the plant as described in the Final Safety Analysis Report (FSAR) within the approved schedule and budget.

It was also made clear that FPL would control the job:

a. When the limited work authorization was lifted in late 1976, because of questions on alternate site considerations, management made the decision to continue engineering and material procurement. This obviously involved risk but in hind-sight was of great benefit (more on this under "Engineering Ahead of Construction").

b. When financial constraints became binding in 1978 and our stock was selling below book value, management did not slow St. Lucie No. 2, but did delay other units.

REALISTIC AND FIRM SCHEDULE

A 65 month Project Master Schedule (first concrete to core load) was established in 1977. Every team member committed to this schedule and FPL did not deviate from it significantly the entire time (see Chart 1 and 2). While core load was missed by five months, St. Lucie No. 2 should be commercial by mid-summer, only two months late.

To ensure a realistic schedule five milestone levels were identified:

Level 1 - Milestone Schedule had 200 activities
Level 2 - 11,000 activities
Level 3 - 32,000 pure construction activities plus 70,000 crosstie restraints
Level 4 - 450 work packages
Level 5 - two week look ahead

The schedule was designed to sequence construction activities to support logical startup rather than emphasizing completion of bulk quantities of concrete, pipe, cable, etc.

As the project developed, several miniprojects were developed and integrated into the master project schedule:

a. Hurricane David recovery (projected 13-wk. delay due to damage by severe storm at 26% project completion point)
b. Detailed licensing
c. TMI items
d. Fire Protection (Appendix R)
e. Reactor Coolant Loop Piping (ASME Section III vs. Section XI)
f. PSI (Preservice ultrasonic Inspection)
g. Construction Completion Checklist
h. System Completion Accelerated Turnover (SCAT). This is one of the keys to timely project completion (see "Early Startup Involvement")

One of the innovations established to enable maintaining a realistic firm schedule was a Change Review Board. This was set up to control changes in the late stages of the project and to postpone those that could be included in the backfit program. Presently, the project has 200 backfit items.

The construction completion checklist was started in the spring of 1982 to help transfer from the area concept of construction into system completion. By the end of 1982, this computerized check list grew to 22,000 items, each individually scheduled, controlled, and monitored. The main site conference room was converted to a "war room." Many proactive, aggressive construction engineers were appointed "milestone coordinators" and given the responsibility to complete groups of items.

By being firm on the 65 month schedule, management was able to foster many innovative construction techniques such as:

a. Reactor Auxiliary Building "Stair Stepping" Concept.

In this plan, emphasis was placed on early completion of the west end of the building. Completion of this end allowed early installation of the more critical equipment i.e., the control room and the reactor auxiliary control boards, the cable vault area, and NSSS auxiliary equipment.

b. Slipforming.

Another innovative construction accomplishment at St. Lucie No. 2 was the "slipforming" of the concrete containment shield wall for the reactor containment building, in lieu of the traditional "step-form" method. This concrete cylinder has a three foot thick reinforced wall, approximately 190 ft. high with an inside radius of 74 ft. It is supported by a ring wall (9 ft. thick and 4 ft. high) which rests on the base mat. The shield wall contains more than 1000 tons of reinforcing steel with another 23 tons of embedded materials such as electrical conduits, grounding cables and anchor bolts.

Wall placement through slipforming of 10,000 cu. yd. of concrete averaged 11½ft. per day, and the operation took place without interruption in only 16½ days in November 1977. Manpower for slipforming averaged 398 craft workers, and the crafts worked three shifts per day, seven days a week until completion. Ebasco engineering and construction personnel also provided around-the-clock support and technical assistance. Immediately after completion of slipforming, construction on the steel containment vessel started inside the shield building.

c. NSSS Installation.

An important benchmark in the NRC's assessment of nuclear plant construction is the installation of the nuclear steam supply system's major equipment; i.e., reactor vessel, steam generators and pressurizer. The project was able to meet this milestone on a progressive schedule by adopting two innovative ideas.

First, was early planning and the decision to erect the containment steel vessel using the "tops-off" approach. Basically, this method provides post-weld heat treatment of the vessel erection before installing the dome. Because of thinner plates, the dome did not require heat treatment and could be erected at a later time. As a result, interior concrete work started months earlier than otherwise possible and ensured that support structures were ready for NSSS installation.

Secondly, the interior concrete was not brought up to the operating level before setting the nuclear vessel. Instead, Ebasco engineering and construction personnel, in conjunction with the heavy rigging sub-contractor and the polar crane manufacturer, simplified the "posting" arrangement for utiiitizing the polar crane in setting the vessels. Using a two-shore (instead of six-shore) polar crane girder support system saved considerable schedule time and enabled construction forces to meet the target date of June-July 1980.

d. Prefabrication of reactor building pool liners and spent fuel pit liners. These were then lifted into place as complete units and acted as concrete forms.

e. Through detailed planning efforts, crafts were able to shop fabricate 145 major assemblies of large bore pipe and valves. Also, large assemblies of small bore pipe and valves were fabricated in site shops. This significantly reduced the number of field welds. Quality and inspection were improved as shop welds are done in a controlled environment. Out of a total of 170,115 welds, approximately 68,000 were made in the shop.

f. All radiography was done on third shift so as not to delay any work on first and second shift.

g. Electrical cable cutting and spooling was done in the shop based on a computerized routing. This saved considerable time in the field particularly on multiple cable pulls.

CLEAR DECISION MAKING AUTHORITY

From the project onset, accountabilities and lines of authority were clearly defined. First, three cost centers were established: the Ebasco New York Office under the direction of the Ebasco Project Manager for St. Lucie; the site under the direction of the FPL site manager; and the FPL General Office under the Project General Manager.

Second, an integrated site organization was established with FPL in control as construction manager. Construction was basically a "Cost Reimbursable" operation with certain specialty contractors. Supervisors numbered approximately 150 FPL persons and 450 Ebasco.

FPL established its QA program with most vendors and contractors. All contractors worked to FPL site construction procedures (with few exceptions).

To further breakdown the project into manageable sections, the construction effort was broken down into:

a. Reactor Containment Building

b. Turbine Generator Building

c. Reactor Auxiliary Building

d. Outlying Facilities

Each area was independent and fully staffed to plan, schedule and perform the work in their area. This was done in lieu of doing the entire job by work discipline, i.e., civil, mechanical, or electrical.

FPL was in charge of construction QC and developed and applied the site QC program to all contractors. FPL supplied key supervision and NDE inspection personnel were supplied by U.S. Testing. These inspectors had to meet FPL's certification program. FPL trained 40% of the specialty inspectors, who were organized on the area concept to give better support to the construction forces. During construction, the waiting time for QC inspections averaged only 15 minutes.

FLEXIBLE PROJECT CONTROL TOOLS

The project control tools as shown in Chart 3 gave the project team the necessary detailed intelligence information to identify problems early and make the necessary decisions to accommodate them. The ability to utilize this detailed information effectively depended on a seasoned, well-oiled team.

Some facts of interest regarding the project control tools:

a. Material Tracking System - 80,000 distinct items were tracked which equated to 5.5 million pieces of information.

b. Weld Control System - 170,115 welds were tracked.

TEAMWORK

The project was organized to meet the project objectives, i.e., to build what we committed to in the FSAR in the time allotted. A matrix project management organization was established with an FPL project general manager, who was given overall authority and responsibility. The project team was made up of members from 21 FPL departments, plus the project managers from Ebasco and Combustion Engineering.

Obviously orchestrating and directing such a large project team in such a complex project took great effort, and involved many people both in and outside FPL. Project team members involved many outside agencies, including the NRC, EPA, State government, Florida Congressional delegation and the Building Trades Council (Construction Craft Unions).

For example, the Florida Legislature passed a bill that would allow the Governor, if necessary, to require counties to participate in emergency planning and drills. While the Governor did not have to invoke this law, it helped to avoid the situation that now prevails in New York.

At one point, the entire Florida Congressional delegation helped support licensing of St. Lucie Unit No. 2 in a timely manner. This led to closer working relationships with the NRC, resulting in record time for review of the FSAR and issuance of the Safety Evaluation Report (SER).

Labor-management meetings were held on a quarterly basis to improve communications with the construction craft unions since a project agreement was not in effect. These open forums paid off because there were NO work stoppages since 1980. These meetings served to involve labor in other productivity improvement efforts such as work sampling, time-lapse photography, foremen delay studies and craft surveys. These efforts resulted in 160 recommendations for productivity improvement of which 100 were adopted and implemented.

A site newsletter called "The St. Lucie Communicator" (sample attached) was published periodically to further involve craft labor in the project.

Several "Open Houses" were held to encourage and permit the workers, their families and residents of the surrounding communities to tour the nuclear unit while under construction. The craft unions were allowed to set up booths to display their skills. Approximately 7,500 visitors toured the unit during one Saturday in 1981.

ENGINEERING AHEAD OF CONSTRUCTION

Nearly 75% of the original engineering package was completed prior to receiving the construction permit. A stay order on construction for eight months permitted engineering and equipment procurement to proceed during this delay period.

Keeping engineering ahead of construction as the project evolved and as changes proliferated became increasingly difficult. This problem was approached in two ways, i.e., forming Task Teams to address specific large problems and forming the Change Review Board to delay as many changes as possible to the backfit program for completion after commercial operation. During the life of the project, 30 different task teams were formed to address specific problems such as IE Bulletin 79-14, Loss of Off-Site Power, Fire Protection, etc.

One of the factors that helped to ensure that the original engineering was satisfactory and would not have to be redone was the implementation of the Independent Engineering Verification Program. This was a team of Ebasco, Combustion-Engineering and FPL professional engineers not associated with the project established to give an independent analysis of key safety-related items being used and installed in the unit.

Another factor that helped to keep engineering ahead of construction was the establishment of ESSE (Ebasco Site Support Engineering) to give real-time response to problems in the field.

EARLY STARTUP INVOLVEMENT

FPL has a philosophy of early acceptance and testing of equipment and systems in order to identify any problems as soon as possible. In support of this goal, a site startup team was established 35 months prior to the scheduled fuel load date. This was not just a token work force since it numbered 64 persons from the site operating department (Nuclear Energy Dept.). This group developed 494 turnover packages including some individual pieces of equipment, partial systems, and complete systems. The early turnover philosophy paid off as problems were found in some unexpected places, like condensate pumps, diesel generators, etc. (standard types of equipment). Again, early identification of problems allowed redesign and fabrication before they became "schedule busters."

ORGANIZATIONAL FLEXIBILITY

Management was not reluctant to change the organization to respond to problems, for example:

a. As startup approached, it was necessary to convert from a bulk quantity approach to a system approach. Based on experience, this was done early to avoid a difficult transition. In addition, six engineers were named milestone coordinators, who acted as miniproject managers in shepherding systems through contruction completion, turnover, startup and acceptance. The site conference room was converted to a "war room" where the real time status of all turnover packages was posted on the walls.

b. Towards the end of piping work, it was necessary to concentrate on problems with piping changes, individual hangers and valves, etc. However progress was practically at a standstill. In analyzing the problem, it was determined that experienced, knowledgeable supervisors and field engineers were needed to take work packages and collect the necessary materials and tools prior to completing the work and calling for final QA/QC inspections. Thus, an almost endless paper chain was avoided. The original piping contractor could not furnish the qualified supervision needed, so Bechtel Power Corp. was brought in to finish the piping work.

c. In the electrical area, we ran into problems involving coordination between Ebasco Engineering and Ebasco Construction. In order to get quicker response and maintain schedule, an Ebasco Vice President virtually took up residence at the site.

d. Already mentioned were the many task teams that were formed to attack specific schedule "busters."

ONGOING CRITIQUE OF THE PROJECT

Many times during the life of the project, independent groups were brought in to review various facets to ensure the project team was not overlooking problems. For example:

a. FPL-QA Department checked all areas.

b. Quality Task Force reviewed the project QA/QC program.

c. Independent Engineering Verification Task Force evaluated the adequacy of the design and translation of design to field installation.

d. Bechtel Power Corp. checked the welding program.

e. Southwest Research Institute monitored Welding QC.

f. Quadrex Corp. reviewed the Containment Cooling System.

g. Bechtel Power Corp. studied the plant AC Electrical Systems.

h. EDS reviewed the Containment Spray System.

i. Theodore Barry & Associates audited the Project Management Organization.

j. Schedule Task Force continually reviewed the Project Schedule.

CLOSE COORDINATION WITH NRC

In order to support the schedule, the NRC was asked to review the FSAR in record time. FPL mobilized to help. For example:

We maintained three engineers and a secretary in Bethesda, Md. plus two engineers full time in FPL administrative offices and three engineers at the site to interface with the NRC resident site inspector and inspectors from NRC Region II. Recognizing the role that NRC had to do, care was taken not to develop an adversary relationship. By maintaining close coordination, FPL was able to answer formally 600 questions in six months. Because of the same close interface, several thousand questions were answered informally, thus avoiding a paper blizzard. The NRC project manager was instrumental in managing the NRC resources to meet the established schedule. At the site the NRC Resident Inspector and Region II inspectors were aggressive in surfacing disagreements early so they could be resolved and dispositioned without impacting the project schedule.

FLORIDA POWER & LIGHT COMPANY
ST. LUCIE UNIT NO. 2
COMPLETED MILESTONE ANALYSIS

ITEM	SCHEDULED	ACTUAL
CONSTRUCTION PERMIT	JUNE, 1977	
START RCB BASEMAT CONCRETE	07/06/77	07/07/77
START INTAKE STRUCT BASEMAT CONCRETE	10/15/77	10/01/77
START T.O. PEDESTAL MAT CONCRETE	12/15/77	10/25/77
START ERECT STEEL CONTAINMENT	01/18/78	12/21/77
START RAB BASEMAT CONCRETE	02/10/78	02/10/78
COMPLETE POST WELD HEAT TREATMENT	12/06/78	01/22/79
START M.S.T. STEEL ERECTION	12/28/78	02/12/79
START RCB INT. CONCRETE	01/17/79	11/07/78
START FHB BASEMAT CONCRETE	05/05/79	06/05/79
START PREOPERATIONAL TESTING	04/20/80	03/19/80
START SETTING NSSS MAJOR EQUIPMENT	06/18/80	06/22/80
COMPLETE RCB OPER FLOOR CONCRETE	09/23/80	10/17/80
SET CONTAINMENT VESSEL DOME	09/26/80	10/04/80
COMPLETE RAB EXT. CONCRETE	12/15/80	12/18/80
COMPLETE LOOP LARGE BORE PIPING	03/14/81	02/06/81
COMPLETE REFUELING WATER STORAGE TANK	04/30/81	04/28/81
COMPLETE RCB EXTERIOR SHIELD WALL CONCRETE	09/06/81	08/11/81
INTAKE COOLING WATER INT. MTR RUN	09/25/81	09/23/81
COMPLETE OCEAN DISCHARGE PPG (KIEWIT)	12/25/81	10/14/81
TURBINE ON TURNING GEAR	12/15/81	12/16/81

CHART 1

FLORIDA POWER & LIGHT COMPANY
ST. LUCIE UNIT NO. 2

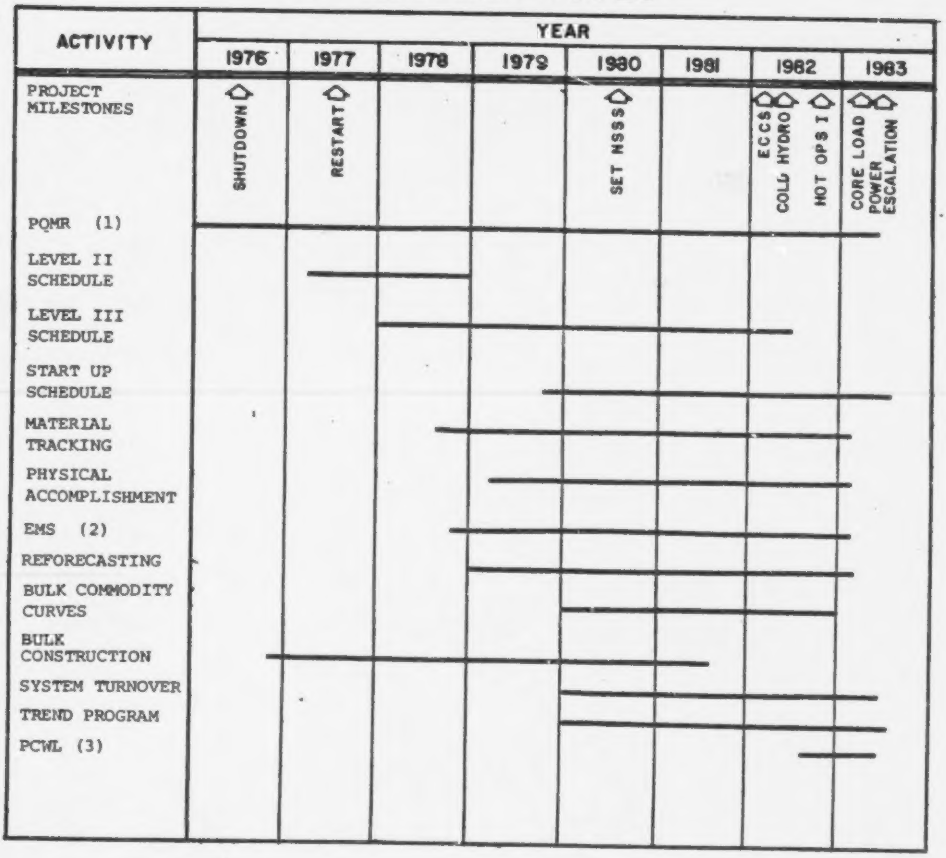
COMPLETED MILESTONE ANALYSIS

ITEM	SCHEDULED	ACTUAL
ECCS FLOW TEST	01/04/82	01/13/82
SECONDARY HYDRO	02/04/82	02/04/82
COLD HYDRO	03/17/82	05/19/82
HOT FUNCTIONAL	07/03/82	10/21/82
ILRT	08/11/82	11/24/82
START SAFEGUARDS TEST	09/20/82	02/23/83
COMPLETE FUEL DELIVERY	09/30/82	12/30/82
START CORE LOAD	10/28/82	04/06/83
HOT OPS II	11/30/82	05/07/83
START CRIT. & PERF. TESTS	12/21/82	06/02/83
START PWR. ESCALATION(5% PWR)	01/05/83	06/13/83
100% POWER	04/04/83	

CHART 2

FLORDIA POWER & LIGHT COMPANY
ST. LUCIE UNIT # 2

IMPLEMENTATION SCHEDULE OF CONTROL TOOLS



(1) Project Quantity and Manhour Report

(2) Electrical Management System

(3) Project Completion Work List

FLORIDA POWER & LIGHT COMPANY
ST. LUCIE UNIT NO. 2

PROGRESS VS. INDUSTRY PERFORMANCE

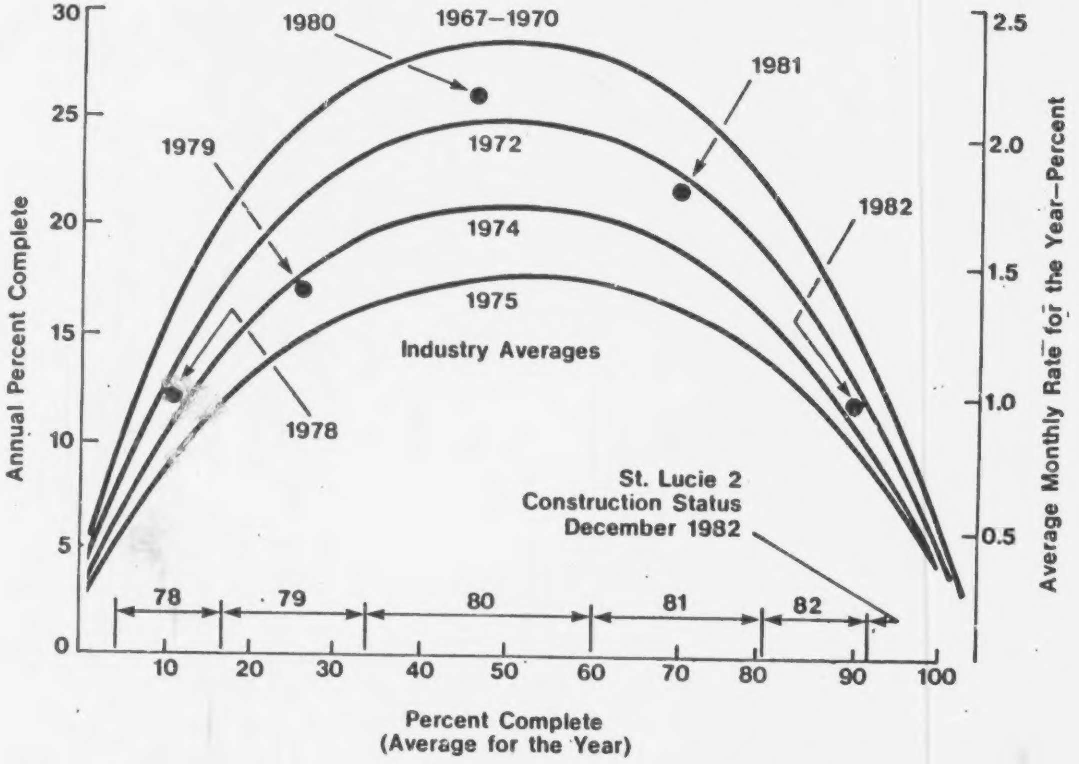


CHART 3

ST. LUCIE 2 COMMUNICATOR

OCTOBER 5, 1982

HOT OPS - - A JOB WELL DONE !

For the past several weeks, all of our efforts on the site have been directed to achieve HOT OPS. For the sake of clarity - HOT OPS is a functional test of the Plant at operating temperatures and pressures, which are achieved through filling systems and running the Reactor Coolant Pumps. (Each Reactor Coolant Pump is equivalent to 3-Megawatts of Heat Input to the system.

As of the Week Ending October 3, 1982 the construction effort related to achieving Hot Ops is essentially complete. Each employee involved in this effort is thanked and congratulated for their help in reaching this significant project plateau.

Before the actual "Hot Operations Tests" can begin, several more things must be completed by Start-Up:

- System Re-entries must be cleared
- System Tagging must be removed
- Valve Line-Up in preparation for the retest of Reactor Coolant Pump 2-B-1 must be completed.

Following the Retesting of the Reactor Coolant Pump, the Plant will proceed into the Hot Functional Test (HOT OPS).

……

PERSONNEL AND PLANT SAFETY DURING HOT OPS

During the Hot Ops testing sequence St. Lucie Unit 2 will change status from a Construction Mode to an Operational Mode. New Hazards will be present, for which you must be alert.

Work with Safety in mind. Be aware of the following points which will be encountered in the next few weeks:

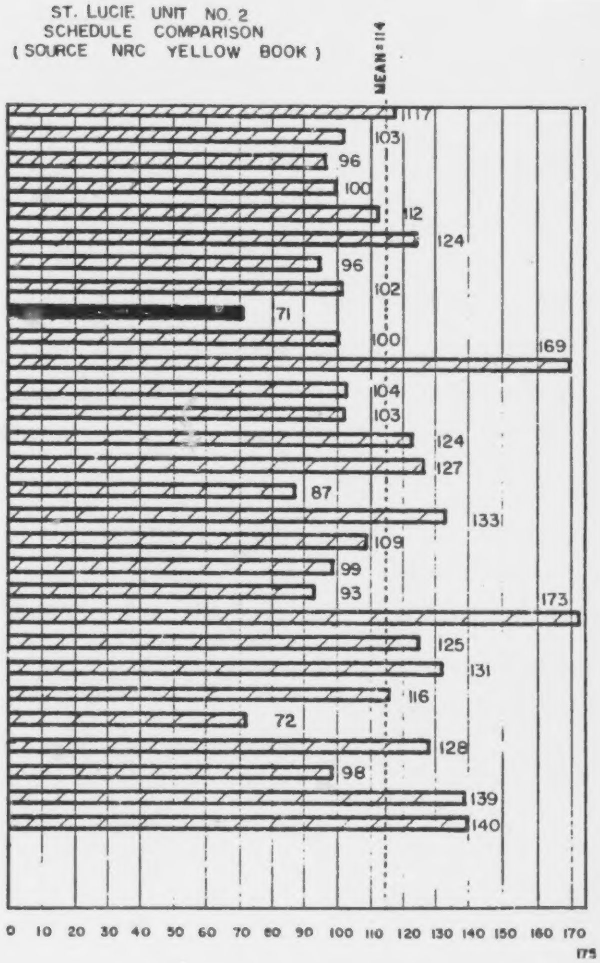
1. When Hot Ops actually begin, no food, cans, bottles, etc. will be allowed in the RCB. Employees may take thermos bottles only into the Containment Building. Lunches will be taken outside the RCB.
2. The Primary Loop will be pressurized to 2250 PSI and heated to 532 degrees F. Do not lean on any equipment, pipe, electrical gear, or pipe or electrical supports during Hot Ops.
3. Piping in the RAB will also be subjected to high pressures and temperatures.
4. The Turbine will be rolled for the first time. High temperature and pressures will affect piping thru the Steam Trestle to the Turbine operating deck.
5. Equipment throughout the plant will be subject to announced remotely operated starts and stops with accompanying loud sounds. Expect these events.
6. Steam will be dumped throughout the test period. Stay clear of steam dump valves and pressure relief valves, as they discharge without notice.
7. Valves, pipe and pump packing as well as pipe joints will be subjected to both high temperature and pressures, and may leak at times. LIVE STEAM IS INVISIBLE! If you suspect a steam leak, DO NOT walk through it! Detour around the area and report the suspected leak to the Safety Department.
8. Most plant electrical equipment will be energized to high voltages. Do not handle or operate any plant electrical equipment without proper clearance. Consider all electrical cables, motors or gear to be energized.
9. Questions concerning proper protective clothing should be directed to the Safety Department.

Many areas will have "restricted" or "limited" access. These are prime hazard areas. Employees are not to enter these areas without proper clearance, and direction from their Supervisor. However, the precautions listed will apply to the entire plant. Following Hot Ops the Start-Up Group will continue operational testing. The entire plant should be considered Operational at that point.

ST. LUCIE UNIT NO. 2
SCHEDULE COMPARISON
(SOURCE NRC YELLOW BOOK)

UNIT	FUEL LOAD	
MCGUIRE 1	1/81	117
LASALLE 1	4/82	103
GRAND GULF 1	5/82	92
SUSQUEHANNA	8/82	100
SUMMER 1	8/82	112
SHOREHAM 1	2/83	124
SAN ONOFRE 2	2/82	96
WATERFORD 3	5/83	102
ST. LUCIE 2	3/83	71
BYRON 1	8/83	100
ENRICO FERMI 2	6/83	169
COMANCHE PEAK 1	6/83	104
CALLAWAY 1	4/84	103
MIDLAND 2	7/83	124
WATTS BAR 1	8/83	127
PALO VERDE 1	8/83	87
WASH. NUCLEAR 2	9/83	133
PERRY 1	11/83	109
SEABROOK 1	9/84	99
WOLF CREEK 1	10/84	93
LIMERICK 1	10/84	173
CATAWBA 1	10/84	125
HARRIS 1	12/84	131
BRAIDWOOD 1	4/85	116
RIVER BEND 1	4/85	72
BELLEFONTE 1	5/85	128
WASH. NUCLEAR 3	6/85	98
MILLSTONE 3	12/85	139
BEAVER VALLEY 2	12/85	140

29 PLANTS



CONSTRUCTION PERIOD
MONTHS

FPL Witness: J.W. Williams, Jr.
Exhibit No. ____ Document No. 10
Page 1 of 1 (January 31, 1983)

ST. LUCIE UNIT NO. 2

MISCELLANEOUS INFORMATION

Owners	Florida Power & Light Co. Orlando Utilities Comm. Fla. Municipal Power Assn.
Total Cost	$1.4 Billion
Man hours expended	16 million
Capacity(net summer '83)	802,000 kilowatts
Architect/Engineer	Ebasco Services
Nuclear steam supply system	Combustion Engineering
Turbine-Generator	Westinghouse Electric Co.
Earthwork excavating/backfilling	712,700 cu. yds.
Concrete used	136,500 cu. yds.
Reinforcing steel	28,039,000 lbs.
Small bore pipe	91,700 linear ft.(17 mi.)
Large bore pipe	78,100 linear ft.(14.8 mi.)
Steel conduit	468,000 linear ft.(88.6 mi.)
Power & control cable	3,911,000 linear ft.(740 mi.)

Major Construction Contractors:

Ebasco Services, Inc., Bechtel Power Corp., Pullman Sheet Metal Co., Peter Kiewit & Sons, Union Boiler Co., Anco Insulation Co., Grinnell Corp., U.S. Testing Co., Chicago Bridge & Iron Co., H.A. Lott Engineering Co.

(The authors regret any omissions and possible inconveniences that might result.)

ST. LUCIE UNIT NO. 2

TRADE COUNCILS REPRESENTED

International Association of Heat and Frost Insulators and Asbestos Workers Local Union 60, Miami Beach, Florida

International Brotherhood of Boilermakers, Iron Ship Builders, Blacksmiths, Forgers and Helpers Lodge 433, Tampa, Florida

International Union of Bricklayers and Allied Craftsmen Local 6, West Palm Beach, Florida

United Brotherhood of Carpenters and Joiners of America Central Florida District Council, Orlando, Florida

International Brotherhood of Electrical Workers Local 323 West Palm Beach, Florida

International Union of Elevator Constructors Local 71 Miami, Florida

International Union of Operating Engineers Local 675 Fort Lauderdale, Florida

International Association of Bridge, Structural and Ornamental Ironworkers Local 402, Riviera Beach, Florida

Laborers International Union of North America Local 767 West Palm Beach, Florida

International Brotherhood of Painters and Allied Trades Palm Coast District Council 76, West Palm Beach, Florida

United Union of Roofers, Waterproofers and Allied Workers Local 67, West Palm Beach, Florida

Sheetmetal Workers International Association Local 130, West Palm Beach, Florida

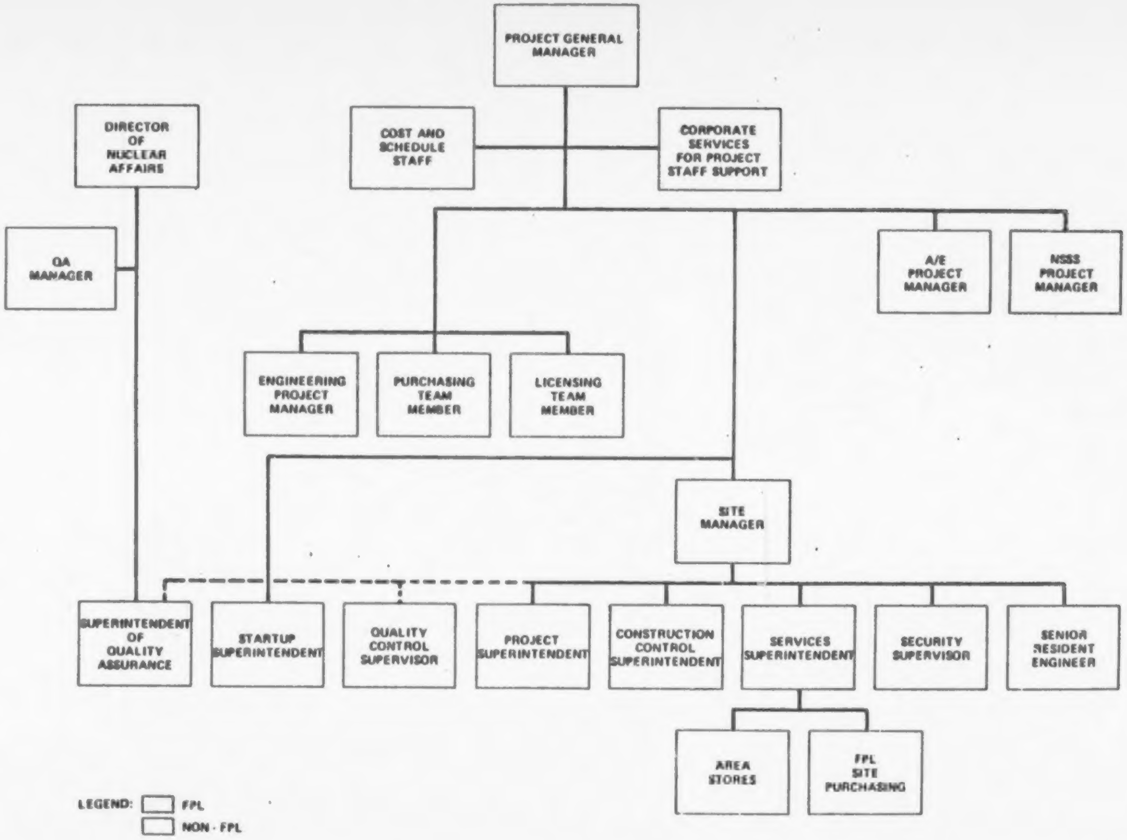
United Association of Journeymen and Apprentices of the Plumbing and Pipefitting, Industry of the United States and Canada Local 630, West Palm Beach, Florida and Local 821 Miami, Florida

International Brotherhood of Teamsters Local 79, Miami, Florida

(The authors regret any omissions and possible inconveniences that might result.)

FLORIDA POWER & LIGHT COMPANY
ST. LUCIE UNIT NO. 2

PROJECT ORGANIZATION CHART


PROJECT GENERAL MANAGER
COST AND SCHEDULE STAFF
CORPORATE SERVICES FOR PROJECT STAFF SUPPORT
DIRECTOR OF NUCLEAR AFFAIRS
QA MANAGER
A/E PROJECT MANAGER
NSSS PROJECT MANAGER
ENGINEERING PROJECT MANAGER
PURCHASING TEAM MEMBER
LICENSING TEAM MEMBER
SITE MANAGER
SUPERINTENDENT OF QUALITY ASSURANCE
STARTUP SUPERINTENDENT
QUALITY CONTROL SUPERVISOR
PROJECT SUPERINTENDENT
CONSTRUCTION CONTROL SUPERINTENDENT
SERVICES SUPERINTENDENT
SECURITY SUPERVISOR
SENIOR RESIDENT ENGINEER
AREA STORES
FPL SITE PURCHASING
LEGEND:
FPL
NON - FPL

TECHNOLOGY ASSESSMENT BOARD
MORRIS K. UDALL, ARIZ., CHAIRMAN
TED STEVENS, ALASKA, VICE CHAIRMAN
ORRIN G. HATCH, UTAH
CHARLES McC. MATHIAS, JR., MD
EDWARD M. KENNEDY, MASS.
ERNEST F. HOLLINGS, S.C.
CLAIBORNE PELL, R.I.
GEORGE E. BROWN, JR., CALIF.
JOHN D. DINGELL, MICH.
LARRY WINN, JR., KANS.
CLARENCE E. MILLER, OHIO
COOPER EVANS, IOWA
JOHN H. GIBBONS

Congreſs of the United States
OFFICE OF TECHNOLOGY ASSESSMENT
WASHINGTON, D.C. 20510

JOHN H. GIBBONS
DIRECTOR

April 5, 1984

The Honorable Marilyn Lloyd
Chairman
Subcommittee on Energy Research
and Production
Committee on Science and Technology
U.S. House of Representatives
Wash[illegible] 20515

[illegible] Mar[illegible]

[illegible] your letter requesting supplemental information [illegible] dardization report. I am attaching answers to the [illegible] xed, and will send a separate copy to Ms. Debbie [illegible]

Sincerely,

John H. Gibbons

Attachment

QUESTIONS & ANSWERS SUPPLEMENT OF NUCLEAR HEARING

QUESTION: Would not a standard design, for multiple plants to be built under one NRC license, in a manufacturing plant, under strict quality and environmental control, be safer than a highly technical system assembled out in a field in the weather?

ANSWER: There is no question that it is easier to control quality to a factory than in the field, but it does not necessarily follow that it is impossible to meet the same standards in the field. In general, however, the approach you suggest makes sense and is one of the main arguments for smaller or modular plants. The economies of scale that have been the driving force behind the movement toward larger plants are also real. We cannot say at this point whether the advantages of factor fabrication, short construction periods and decreased financial exposure outweigh the loss of economy of scale, but there appears to be a good chance they will. The impact on safety will be harder to define. Safety is probably more dependent on the specific reactor technology involved and the care with which it is designed, built, maintained and operated than whether it is factory or field assembled. In general, as we concluded in our standardization report, it is easier to perfect a standardized technology and to improve the human element since training and the sharing of experience is expedited.

QUESTION: Could not such shop assembled plants then be certified by the NRC?

ANSWER: Yes, but that is not unique to them. General Electric and Combustion Engineering already have Final Design Approvals from the NRC for their reactors, presumably obviating the need for a design review if a utility orders one of these reactors. This does not mean that new safety concerns will not emerge and have to be addressed, but that would also apply to factory fabricated modules. In general, a mass produced reactor with a design approval should be more convincing to a utility concerned over regulatory unpredictability.

QUESTION: While the OTA standardization report states that Architect/Engineers do 90% of the plant design and construction, and that is certainly the lions share, what is your opinion of having the reactor manufacturer, or consortium of manufacturers, who knows more about the core geometry and the metallurgy be responsible for plant design?

ANSWER: Design features that are critical to the integrity of the core are already largely the responsibility of the vendor. Expansion of their responsibility to all safety related systems appears to be a good way of integrating plant design, but it should be noted that in general, A/Es are more experienced with pumps, pipes and wiring. One difficulty is that the definition of what is important to safety keeps expanding. Single point responsibility for plant design and construction is in general a good approach, as we discuss in our report, Nuclear Power in an Age of Uncertainty, and it appears to be the trend in industry.

QUESTION: Would you discuss the Department's perspective of several experts that smaller reactors may have advantages in today's markets and projected markets over larger multi-megawatt-size plants. Are there advantages in cost or otherwise in fabricating and installing small breeder reactors? Would you comment on the savings potential in terms of interest paid in construction if times are reduced from 12 years to 9-to-5 years?

ANSWER: There is a virtually complete consensus that reactors grew too large too fast. The present generation of designs is maturing, however, and there is considerable dispute over whether it would be advantageous on the whole to move back to smaller light water reactors. Our report Nuclear Power in an Age of Uncertainty discusses these issues in detail (pp. 105-107) and concludes that smaller reactors look promising, particularly in reducing financial risk, but the situation is still rather ambiguous. The economies of scale of large plants are significant, and if construction costs of new plants can be controlled through tighter management, better regulation and standardization, and mature designs, small plants may not be competitive. There is reason to doubt whether all these conditions can be met or whether enough decisionmakers will believe they will be met, however. Under such conditions, small reactors may be the only reactors that could be ordered. Innovative approaches to design and construction could also offset the economies of scale to a large extent. One thing that does appear clear is that non of the American NSSS vendors is ready to invest the funds needed to market a new, small LWR. Thus, if one is to be made available, it will only be with government assistance.

Reactors other than LWRs present somewhat different conditions. Designers are more flexible because no one has a large investment in any size design, and the safety advantages of keeping gas or liquid metal cooled reactors small appear to be more pronounced than for LWRs. Small breeder reactors with integrated reprocessing and refabrication facilities are in a preliminary stage of design, but appear to be quite promising. Because of its compact core, this reactor is more adaptable to factory fabrication than any other. Capitalizing on passive safety features and factory fabrication could lead to a design with very competitive costs.

Interest costs are a major portion of the total costs of nuclear powerplants. Reducing construction schedules will significantly reduce these costs. The table on page 64 of Nuclear Power in an Age of Uncertainty (attached) shows that reducing construction from 12 to 8 years drops the addition to overnight construction costs for interest by 83% (case 1 conditions). For instance, if direct charges for labor and materials are $1000/kw, interest over 8 years would be $920 and over 12 years would be $1670. Note that if constant dollars are used, the effect of construction schedules on interest charges is much less dramatic.

Table 8.—Additions to Overnight Construction Cost Due to Inflation, Escalation and Interest During Construction (in constant and current dollars)

	Percent increase in constant dollars		Percent increase in current dollars	
	8-year leadtime	12-year leadtime	8-year leadtime	12-year leadtime
Case 1: 7% general inflation, 0 escalation, 10% interest rate	+ 12	+ 19	+ 92	+ 167
Case 2: 7% general inflation, 0 escalation, 12% interest rate	+ 21	+ 33	+ 107	+ 200
Case 3: 7% inflation, 2% escalation, 12% interest rate	+ 30	+ 48	+ 123	+ 233
Case 4: 5% inflation, 0 escalation, 10% interest rate	—	+ 34	—	+ 140
Case 5: 9% inflation, 0 escalation, 14% interest rate	—	+ 33	—	+ 273

NOTE: "Escalation" is defined as the increase in the unit costs of labor and components used in nuclear plants (with no change in quality) above the rate of general inflation. For inflation of 7 percent, an interest rate of 10 percent corresponds to a real interest rate of 3 percent, an interest rate of 12 percent corresponds to a real interest rate of 5 percent.

SOURCE: For the calculation, Wilfred H. Comtois, "Escalation Interest During Construction and Power Plant Schedules," Westinghouse Power Systems Marketing, September 1975.

Congressional Research Service
The Library of Congress

Washington, D.C. 20540

May 25, 1984

TO : Subcommittee on Energy Research and Production
House Committee on Science and Technology
Attn: Nancy Jeffery

FROM : Carl E. Behrens
Specialist in Energy Policy
Environment and Natural Resources Policy Division

SUBJECT : Questions on Small Nuclear Plant Study

The following responds to the questions submitted to me following my testimony before the Subcommittee on February 7 on the subject of the CRS study, "Economic Potential of Smaller Sized Nuclear Plants in Today's Economy."

QUESTION: Several Department experts have the perspective that smaller reactors may have advantages in today's markets and projected markets over the larger multi-megawatt-size plants. Are there advantages in cost or otherwise in fabricating and installing small breeder reactors? Would you comment on the savings potential in terms of interest paid in construction if times are reduced from 12 years to 9 to 5 years?

ANSWER: The CRS study examined the economics of small versus large nuclear plants in a model utility's total financial environment. The large plant was a conventional 1,200-megawatt Light Water Reactor; the small, 400-megawatt plant was assumed to cost between 7 percent and 24 percent more per kilowatt than the large one. Such an assumption implied a technology other than the conventional LWR, which would be at a much greater cost disadvantage. But we did not specify a particular technology, other than note that designs of several types of nuclear plants gave promise of falling within our assumed cost range. Thus if a 400-megawatt breeder could be built within our cost assumptions (through advantages in fabricating and installation or other design characteristics), our study showed that a utility would have much less trouble financing three such units than it would one large 1,200-megawatt LWR. It might even find that the total utility cost of producing power would be less when it built small units, if load growth was very slow and interest rates very high.

Construction time is clearly a very important variable in construction costs, particularly time added to the construction after substantial investment has been made in the project. Much of the cost effect of construction delays in such cases derives from increased interest payments. An example can be found in the case of the Marble Hill project. In October 1983, Public Service Indiana announced a 24-month extension in the construction schedule of the project, and released a revised estimated cost of approximately $7 billion. According to PSI's Annual Report for 1983: "About 74%, or $1.4 billion, of the increase was due to the additional cost of capital during the construction period." (p. 5). Thus a two year delay in completion resulted in increased interest charges which by themselves raised the cost of the project by 27 percent. (The Marble Hill project was later cancelled by PSI, largely on the basis of inability to continue financing the construction.)

The CRS study did not investigate the construction-time variable directly: modelling complexities made it impossible to vary the construction time significantly, so it was assumed that both large and small plants would take the same time, 8 years, to construct. It should be noted that construction times for conventional LWR's in recent years have varied widely, from approximately 6 years to 10, 12, or even more years. It is intuitively logical that construction times for small projects should average less than for large ones. However, there appears nothing inherent in the technology of large LWR's to prevent their being completed in 6 years or so, if financing is available and adequate growth in demand is projected. The significance of the CRS study to this question lies in the fact that building large nuclear units caused financing difficulties, as measured by the coverage ratio, in all cases, even when demand was projected to grow relatively rapidly. Building small nuclear units, on the other hand, caused no financing difficulties, even when demand growth was extremely low and interest rates very high. This implies that delays in construction, arising from financing difficulties, could be avoided by building small plants.

QUESTION: In the establishment of parameters for your study, what consideration was given to the standardization potential of smaller units? What installation economies do you believe could be obtained from repetitive manufacture?

ANSWER: Standardization and modular manufacture were among the factors used to justify our assumption that a 400-megawatt plant could be built that was only 7 to 24 percent more expensive per kilowatt than a conventional 1,200-megawatt LWR. It was necessary to assume such technological advantages because a conventional 400-megawatt LWR would appear to cost much more per kilowatt--perhaps 50 to 100 percent more than a 1,200-megawatt unit. (There is no way of quantifying the economies of scale between large and small conventional LWR's since no small units have been built in recent years.) The CRS study thus implicitly included these technological characteristics in its assumptions, but did not attempt to quantify any individual technological advantage.

QUESTION: What responses from industry have you received to date on your report's conclusions?

ANSWER: The general response has been that it confirms what has become a regrettable fact of life in today's economy: financing large powerplants is an extremely difficult and chancy process. Thus the finding that building smaller units reduced the financing risk was received with great interest.

Other industry commentators said that the CRS study of nuclear economies of scale complemented similar studies of scale in coal-fired plants, and noted that coal units under construction at present range in size from very small to very large.

For some the study's conclusion, that a market probably would exist for small nuclear units under given conditions, was taken to imply that no market existed for large plants. No such implication was intended. For a large utility, or one whose load was growing rapidly, building many small units would have significant disadvantages which could be overcome by building a fewer number of large ones. Nevertheless, the general attitude of the utility industry today appears to be that large, conventional LWR's present so many problems that they would not be likely to order new ones in the foreseeable future. This attitude was a major factor in the conclusion of the Office of Technology Assessment's study (Nuclear Power in an Age of Uncertainty): "Without significant changes in the technology, management and level of public acceptance, nuclear power in the United States is unlikely to be expanded in this century beyond the reactors already under construction." (p. xi).

Department of Energy
Washington, D.C. 20585

April 3, 1984

Honorable Marilyn Lloyd
Chairman
Subcommittee on Energy Research
and Production
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Madam Chairwoman:

On February 8 Assistant Secretary Shelby T. Brewer appeared before your Subcommittee to discuss the FY 1985 budget request.

Following that hearing, you submitted written questions for response to supplement the record. Enclosed are the answers to those questions.

If you have any questions, please call Diana Diamond or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

for Thomas H Pretorius

Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Ms. Nancy Jeffery

POST-HEARING QUESTIONS AND ANSWERS

RELATING TO THE

FEBRUARY 8, 1984 HEARING
BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES
WITNESS: SHELBY T. BREWER
ASSISTANT SECRETARY FOR NUCLEAR ENERGY
DEPARTMENT OF ENERGY

Question: The breeder R&D program organization as presented in the Department's budget request has many features common to a more general advanced reactor development program. Could not the base R&D program organization encompass more than the breeder, thereby allowing use of the high quality personnel and facilities that comprise the breeder base technology program on other advanced reactor R&D efforts as well?

Answer: There are numerous points of commonality among advanced concepts. The ability to achieve major reductions in cost and schedule through shop fabrication or through modular designs, and the ability to develop designs which do not depend on prompt operator action or active safety systems, are objectives which are common to all such programs. More importantly, solutions found in one program may be applied to others. The technical expertise in the breeder development program, and the unique test facilities which we have developed and maintained over the years, are a valuable asset which can and will be utilized to resolve problems common to all the new designs.

Additional areas of both direct and indirect technical support by the breeder base program for other reactor types are being pursued and others will be undertaken as needs become better defined. Currently, we are performing materials irradiation tests for the Space Reactor and Fusion Programs. This would not be possible but for the continued operation of the FFTF and EBR-II facilities. Also, the TREAT reactor is being utilized to conduct tests as part of EPRI's evaluation of the Light Water Reactor source term. The facilities at ETEC are being used as part of EPRI/NRC's evaluation of containment building valve performance at specified conditions.

Demonstration of real time accountability, anti-proliferation safeguards, and reduced radiation exposures are the objectives of our fuel fabrication line being installed in the Fuels and Materials Examination Facility at the Hanford Engineering Development Laboratory. This fully automated, remotely operated fuel fabrication line can serve as the model for all future reactor fuel fabrication facilities. Furthermore, the economics of automated fuel fabrication should further improve the favorable energy cost of nuclear power generation.

The results of our materials program are compiled in the Nuclear Materials Handbook and in the national standards formulated by the engineering societies. Thus, the output of our materials program has been serving the needs of all DOE reactor projects, as well as fusion and fossil energy programs, and the regulatory bodies. Our efforts on structural design for earthquake resistant buildings and components have broad applicability with direct benefit to most of the Department's energy conversion programs.

We will continue to explore ways to broaden the utilization of these facilities and programs.

Question: What is the Department's intentions for responding to our Committee language last year requesting an intensive technology transfer effort for the Water Cooled Breeder?

Answer: Attached is a copy of Dr. Brewer's response for the record to this exact question which was asked in the HS&T hearing of February 8th.

Question: Report language accompanying the Committee's FY 84 authorization bill called for an intensive technology transfer effort for the Water Cooled Breeder. To date, the Subcommittee has not received a departmental response and I note the language calls for a response. What is DOE's intention for responding to the language of last year requesting an intensive technology transfer effort in the Water Cooled Breeder program?

Answer: The response to the language in the bill is that technology transfer is now and has been an important part of the Water Cooled Breeder program; accordingly it is not necessary to earmark a specific portion of the Water Cooled Breeder program funds for that purpose. The Department of Energy fully agrees with the Committee's desire to ensure industry's knowledge of the light water breeder technology. The Department believes actions being taken are accomplishing this goal.

Throughout the Light Water Breeder Reactor program, extensive efforts have been made to disseminate the technology to the nuclear industry and to academia. This includes having:

a. entered into formal information exchange programs with the commercial reactor suppliers;

b. published over 300 technical reports on Light Water Breeder Reactor technology; and

c. presented or published in technical journals over 180 technical papers.

These reports and papers have been distributed to industry and universities, which have found various applications for the sophisticated computer codes and technology.

The General Accounting Office confirmed industry was knowledgeable about the Light Water Breeder Reactor program and wanted to know the results of the Department's core evaluation effort.

As part of its R&D effort to ensure a viable nuclear option for the future, the Department will continue work applicable to the various reactor technologies--pressurized water, liquid metal, and gas cooled. Completing the core evaluation phase of the Light Water Breeder Reactor program is a vital part of this effort because it builds on the already substantial technology base established over more than a quarter century of operating numerous pressurized water reactor power generating plants.

A Light Water Breeder Reactor core successfully operated in the Shippingport Atomic Power Station generating electrical power for almost twice its original design life. The core evaluation work that remains to be done will:

a. provide important information that is equally of interest in non-breeding pressurized water reactor designs; specifically the performance of fuel, structural materials, and various engineered features in conditions of extended fuel burnup; and

b. determine the amount of breeding obtained--a fact of vital importance in being able to exploit the thorium/uranium-233 cycle which is an almost limitless resource.

In summary, advanced reactor technology, including Water Breeder Reactor technology, remains an important part of the Department's

R&D effort. The General Accounting Office found that completing the Light Water Breeder Reactor core evaluation work as currently planned was worthwhile and the most cost effective way to complete the Light Water Breeder Reactor program.

Question: How does this program fit into a restructured breeder reactor systems R&D program?

Answer: The Light Water Breeder Reactor (LWBR) effort is a part of the Breeder Reactor Systems only to extent of the breeding properties of the technology being pursued. Work on the LWBR technology is nearing completion with the core evaluation work that is presently underway. FY 1987 funding will complete this effort and the LWBR will be phased out. Therefore, the LWBR goals and objectives will not change and the program is not being considered in regard to the restructured BRS program.

Question: Could ETEC be used to test HTGR steam generators and circulators (as well as components for the external concepts)?

Answer: Yes. The Energy Technology Engineering Center (ETEC) was established in anticipation of a broad range of testing requirements for the Department of Energy's programs. In the transition from the predecessor Liquid Metal Engineering Center (LMEC), the capabilities of the Center were broadened and made more versatile. Approximately 25 percent of the activities at ETEC are conducted for non-liquid metal programs. When the high temperature gas cooled reactor project needs to test steam generators, gas circulators, or other power conversion components, ETEC facilities will be available to accommodate the test requirements with some modifications.

Question: The Secretary transferred the thermionics program to the Space Reactor Program in FY 1984. The budget submission for FY 1985 does not reflect this addition of some $2.6 million. Why not? What is the actual Departmental budget for FY 1985? Does it include thermionics development funding? Wasn't the FY 1984 funding level $7.6 million, including the $2.6 million for thermionics? Why is the FY 1985 request only $4.3 million?

Answer: The budget for the Space Reactor Program for FY 1985 was submitted by the Department to the Administration before a final decision was made to transfer the thermionics program to the Space Reactor Program. As a result, the FY 1985 budget submission to the Congress does not reflect the addition of $2.65 million to the Space Reactor Program in FY 1984. The Departmental request for the Space Reactor Program for FY 1985 is $4.5 million. This includes funding for the thermionic systems evaluation efforts.

The initial appropriated funding level for FY 1984 was $5 million. When the thermionics program was transferred to the Space Reactor Program, the overall level increased to $7.6 million.

The current funding levels for the technology assessment phase of the program were defined when the tri-agency agreement was established. The program thrust in this phase is focused on obtaining information necessary for a July 1985 decision on selecting a specific system concept for engineering development and ground test. The requested funding level for FY 1985 is adequate to obtain the required feasibility information.

Question: Please explain the rationale behind your regrouping of the previous five technology disciplines into three broad categories that, at first reading of the program description, appear to be doing the same tasks as in prior years? How do these program elements support the evaluation of new, innovative reactor designs?

Answer: In presenting the breeder base program, the budget and reporting categories (B&R) used in budgetary control must be considered. The technical content of the various technology disciplines may not exactly fit a specific B&R category. The previously listed B&R categories were structured in order to provide the needed input for the then ongoing projects--namely FFTF, CRBR, and LSPB, as well as the generic requirements. A number of the technology inputs reached the stage of development that potential users, like the innovative reactor designers, can build on the results obtained to date. It was with this background in mind that the program management was restructured into three broad categories: power conversion technology, which could be considered as the nonnuclear balance of plant engineering that is ready to serve the innovative concepts, as well as other non-liquid metal systems because of the commonality of the technology; fuel performance and supply, which has a more restricted function considering the reduced fuel requirements that result from the termination of CRBR and LSPB; and nuclear systems and technology, which can be looked upon as the nuclear island entity with physics, safety, and part of our materials programs combined into a technical unit to provide an economically competitive nuclear steam supply system that maximizes the capability to operate safely, without reliance on prompt operator action or active emergency systems.

Question: Our review of the SP-100 program suggests that progress has been made over the past year in identifying technology needs. Could you comment on the need to begin some pre-engineering work in FY 1985 and perhaps enhance some mission identification and analysis work as well?

Answer: The current program is focused on obtaining only feasibility data and not engineering data. The distinction is that while feasibility data may show, for example, the basic material compatibility of a clad, coolant, and fuel combination, it would not be a full characterization of that particular combination of elements. The current plan is to initiate more intensive activities in FY 1986 following concept selection and initiation of the engineering development phase.

In our view, mission development is proceeding at a pace fully commensurate with the system concept definition and technology work. We fully expect commercial, civil, and military missions to be sufficiently well-defined to support the start of engineering development of a power system in FY 1986. User "pull" for a specific mission and space system should materialize between FY 1988 and FY 1992. This would allow orderly flow into a user-funded flight applications program.

Question: Test facilities operation absorb about 54 percent of the breeder base operating budget. Are there ways to reduce these costs, so that more operating funds could be available for such tasks as the breeder fuel cycle work?

Answer: The Department has been pursuing an aggressive plan to consolidate and eliminate test facilities that are marginally useful to the Breeder Reactor Program. For example: two zero power test reactors have been decommissioned; the Engineering Test Reactor has been dismantled; and the post-irradiation examination capability planned for the Fuels and Materials Examination Facility has been indefinitely deferred. Operating expenses have been further reduced at all test facilities by cutbacks in the number of employees at these facilities. Opportunities for additional cost reductions will continue to be pursued in FY 1985. We are also considering projects that will provide essential steam generator endurance test information while further reducing facility operating expenses. Furthermore, we have restructured our program so that the operation of our facilities, and consequently the costs incurred, support the highest priority activities.

Question: Why is BRET being terminated? Why not incorporate this effort within the breeder base technology program?

Answer: We will complete certain design activities for the BRET project in FY 1984. Our FY 1985 budget request contains no proposed funding for the BRET project because of budget constraints and the need to reexamine the objectives and scope of this project to be consistent with the restructured breeder program. Demonstrated closure of the breeder fuel cycle remains an important element of the restructured program.

Question: How could university participation in mainline fission R&D activities be increased?

Answer: There were 23 universities among the Department's top 100 contractors, according to the Department's "Annual Procurement and Federal Assistance Report." The universities enjoy a great degree of latitude in choosing their mission and R&D activity which is in accordance with their long range goals. The base program has always been receptive to new and innovative ideas generated by the universities. Furthermore, we have encouraged the universities to work closely with our mainline contractors and national laboratories to forge a closer relationship between the universities and the base program. We feel that the funding allocations and the nature of the work performed at the universities reflect the universities' preferences, and is in keeping with their own internal goals.

Question: What problems do you anticipate among regulations and regulators in the development of High Temperature Gas-Cooled reactors? How would you alleviate these problems?

Answer: One reason for the renewed interest in the HTGR is that theoretically, it could be easier to license. However, the reason for the use of the word 'theoretical' is that unless there is fundamental reform of the Nuclear Regulatory Commission's licensing and regulatory process and management system, there will never be another commercial nuclear plant order in the United States, regardless of the type of reactor. It is urgent that Congress address licensing reform as soon as possible.

In anticipation that the regulatory problems will be resolved, we will be working closely with the Nuclear Regulatory Commission to begin to develop an approach to resolving HTGR specific regulatory issues on a timely basis.

Question: Why did DOE decide to cease funding for the Breeder Reactor Engineering Test facility?

Answer: The Administration chose not to request funds for the Breeder Reactor Engineering Test facility in FY 1985 due to overall budget constraints and the need to reexamine the objectives and scope of this project to be consistent with the restructured breeder program. We will seek to structure the BRET in the outyears in a way that will secure the necessary support and allow the project to continue.

Question: What market share does the uranium enrichment program seek? Domestic? Foreign? On what was that goal based?

Answer: By offering competitive prices and flexible, attractive terms to our customers, DOE intends to compete to retain all existing contracts and to acquire any new contracts that may evolve in the future. DOE believes by retaining this competitive posture and assuring that we are responsive to customer needs, the United States can retain a majority of the world enrichment market.

Question: In the inherently safe reactor concept program, what are your plans for early involvement of the Nuclear Regulatory Commission? Do you believe their early involvement would be beneficial or detrimental?

Answer: The Department of Energy (DOE) certainly believes that early involvement of the Nuclear Regulatory Commission (NRC) is beneficial on any advanced reactor program. We have already held discussion with them on both the liquid metal cooled and high temperature gas cooled concepts. In the Commission's recent meeting on February 27, 1984, with the NRC staff, the staff was directed to work with DOE and we intend to cooperate fully in this activity.

Question: Recent reorganization at DOE appeared to separate the responsibilities for uranium enrichment operations and research and development. Please comment on that point. We would certainly want assurance that such separation does not jeopardize the close liaison which must be maintained between those two authorities.

Answer: The Secretary of Energy had announced his intention to effect a change in the organization of uranium enrichment. We are mindful of the important liaison between the operational aspects of the uranium enrichment and the research and development programs. Any organizational realignment that occurs will consider these aspects carefully and accommodate them in a manner that results in most effective operation of both efforts.

GA Technologies

GA Technologies Inc.
P O BOX 81608
SAN DIEGO, CALIFORNIA 92138
(619) 455-2080

HAROLD M AGNEW
President

March 28, 1984

The Honorable Marilyn Lloyd, Chairman
Subcommittee on Energy Research
and Production
Committee on Science and Technology
U.S. House of Representatives
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Lloyd:

I am very pleased to respond to your letter of March 20, 1984 requesting information to supplement the record of your Subcommittee hearing on February 8 of this year. The additional record in the form of answers to the questions accompanying your letter are attached.

Once again, I would like to thank you and the Subcommittee for the continuing support of the High Temperature Gas-Cooled Reactor Program and to express my support for the initiative you have undertaken to reestablish nuclear power as a viable and acceptable power option in this country.

Sincerely,

Harold M Agnew

Attachment

bcc: N. E. Carey
R. A. Dean
T. A. Johnston

Question No. 1:

To what extent does the Inherently Safe Reactor concept apply to reactors other than the High Temperature Gas-Cooled technology?

Answer No. 1:

GA has not diverted any significant resources to the evaluation of reactors other than the High Temperature Gas-Cooled Reactor to conform to the goals for an Inherently Safe Reactor as outlined by the Committee on Science and Technology. Our general knowledge of other reactor systems does suggest, however, that designs could be developed which would provide for a higher degree of inherent safety (i.e., less reliance on active engineered safeguard systems) than embodied in current designs.

In the case of all HTGR's, a large degree of safety is derived from inherent features of the concept including the use of an inert, single phase coolant; the presence of a very large, fixed heat capacity to absorb after-heat in the event of an accident and the use of core and fuel structural materials which provide large temperature margins prior to the onset of fission product release in the event of an accident. These inherent properties are augmented in some HTGR designs by the use of a Prestressed Concrete Reactor Vessel (PCRV) and generally supplemented by engineered safeguards to meet the desired safety goals.

In the case of the "modular" HTGR the inherent features have been augmented to take advantage of natural convection and the overall thermal output constrained so that even in the event that all active systems are unavailable, that the core temperature will remain below the temperature at which fuel degradation would occur. The capability to satisfy the desired safety goals without resorting to active safety systems has been termed "passive safety".

Similar approaches may well be applied in various degrees to other reactor systems to either enhance their inherent levels of safety or to achieve "passive safety". The PIUS reactor provides enhanced heat capacity through the use of a large water volume contained with a PCRV and a "poisoned" coolant pool to achieve the passive shutdown of the system under abnormal operating conditions. We also understand that the current designs of modular liquid metal reactors make use of natural convection to raise the level of inherent safety. We are not sufficiently familiar with these other reactor systems, however, to define the extent to which they can be practically designed to conform to the House Science and Technology Committee goal for Inherently Safe Reactor concepts.

Question No. 2:

What extent of market potential do you estimate for a modular HTGR facility?

Answer No. 2:

The potential market for the modular HTGR reactor system includes the use of multiple modules for mid-range additions of base load generation and as single units to provide incremental additions of electric power. The system also appears to be of an ideal size (approximately 250 MWt)be used for co-generation (electricity and process steam) or for the dedicated production of process steam for industrial uses. The potential also exists to replace existing fossil boilers with modular HTGR steam systems which have the same operating conditions. Export of the system is expected to be another major market. Because of the passive safety features of the modular system it appears particularly attractive for export to developing nations which do not in all cases have the strong, technical infrastructure normally required to assure safe plant operation.

With the prevailing load growth, institutional and financial uncertainties, it is difficult to forecast the market potential for any reactor system including the modular HTGR. It does appear, however, that significant additions of generating capacity will be required during the late 90's and beyond to satisfy even modest load growth forecasts and to replace older less efficient systems. With the long history of support of the HTGR by a large segment of the utility industry it appears reasonable to assume that the modular HTGR can share in this market.

A key factor in assessing the share of the market available to the modular HTGR will be the economics of the system relative to the alternate systems. It is anticipated that individual modular units will have substantially lower unit capital costs ($/Kwe) than would be projected for "conventional" nuclear plants scaled down to the same size. This results both from the simplifications embodied in the design, the reduction in the number of safety related systems, the localization of nuclear requirements, the savings inherent in an increased level of fctory fabrication and from shorter construction schedules. Additional reductions would be expected to result from the deployment of multiple modules at a single site. Studies to date indicate that the power costs for multi-module HTGR installations are at least comparable to the costs estimated for mid-size nuclear or coal fired fossil units. If these studies are verified the greater operating and planning flexibility, and reduced project schedule and cost risks would favor the selection of the modular HTGR for many applications.

Question No. 3:

The subcommittee has been advised that recent surveys indicate public aversion to nuclear power plants by the American public. How would you propose to sell the "Inherently Safe Reactor concept" to that American public?

Answer No. 3:

The current public aversion to nuclear power plants results largely from the public perception that the original promises made regarding nuclear power were oversold and have not been kept. This includes the promises of "too cheap to meter", "the safest and best regulated industry", "the scientists know what they're doing", etc. Although the industry can take justifiable pride in its record of safety the public and media perception is of a Three Mile Island near disaster, of reported incidences of poor Q.A. and falsified records, and of the need to establish evacuation plans for systems which are claimed to be safe. The economic benefits derived from the early nuclear plants have passed from the public mind and have been replaced by "rate shock", and by headlines indicating that nuclear utilities are in deep financial trouble. These and other factors have led to a general loss of trust by the public in the institutions associated with the nuclear industry.

With this background it will be extremely difficult to "sell" the American public on an Inherently Safe Reactor. We believe that it will be necessary to verify through "public" testing the safety claims of the "Inherently Safe Reactor" concepts. Specifically in the case of the modular HTGR we have recommended that a prototype plant be built and run through a series of tests to demonstrate that even the so-called low probability accidents can be accommodated without the intervention of active safety systems. The construction and testing of such a prototype would also verify "type certification" of the concept, verify that evacuation planning should not be required and establish the economic viability of the system. This type of demonstration we believe can reestablish the confidence and support of the public in nuclear power.

April 5, 1984

Ms. Nancy Jeffery
Subcommittee on Energy Research
and Production
B-374 Rayburn House Office Building
Washington, D.C. 20515

Dear Ms. Jeffery:

As promised, in my March 30 memo to you, are Dr. Charles Storrs' answers to the subcommittee's questions regarding the HTGR Modular Reactor. Again, please excuse the delay.

If you have any questions, please give me a call on (202)-429-9180.

Sincerely yours,

Enclosure

Question: What market surveys has your company made to determine the potential for a modular, standardized HTGR facility?

Although Combustion Engineering maintains continuously updated surveys of the market for power plants in general, specific surveys have not been made concerning modular, standardized HTGR facilities. Responses to such a survey would be highly dependent upon the availability of reasonably firm projection of costs, schedules and licensability. These issues are further addressed in the response to the next question.

Question: What information can you provide to a utility so that it, in turn, can assure the public that such a facility is a beneficial method of power generation?

It is my view that the utilities require stability of the licensing process, predictable costs, and predictable schedules in order to evaluate proposed methods of power generation from an economic point of view. In addition, they require the support, or at least the acceptance of the public for the chosen method. Despite the unblemished and unparalleled safety record of the commercial nuclear power industry, as evidenced by 24 years of operation without injury to the public, people are concerned about the safety of nuclear power. Finally, since the public has chosen to penalize the utility industry for overestimating load growth, it is important that the construction time be reduced so that more accurate projections of requirements can be made.

The modular HTGR program addresses all these issues. Stability of licensing requires a forward-referenceable Final Design Approval (FDA) before the utility commits major funds. New licensing requirements not incorporated in this FDA must be based upon significant new information, and, except for emergency situations, should be the result of public hearings at which the benefits of the proposed changes could be weighed against their cost. The original FDA could be based upon a comprehensive series of tests on a full-scale prototype of a standard modular plant, including design-basis and beyond-design-basis events. The culmination of this test series might be a loss of coolant pressure and flow, with no control rod insertion and with decay heat removal solely by the inherent, passive means of radiation and conduction to the vessel, following a prolonged period of full power operation.

If the modular HTGR can withstand this extreme test (appropriately witnessed by representatives of the media and the nuclear critics), the FDA will rest upon an extremely solid and convincing foundation. Furthermore, the tests will largely resolve the doubts and apprehension of the media and the public. Uncertainties arising from extrapolation in size or performance will be avoided, since subsequent commercial plants will be copies of the test article (incorporating only those changes required by the FDA). The safety of the modular HTGR is almost entirely associated with the nuclear steam supply system itself, and this will be built, assembled and tested in the factory prior to shipment. This will provide much improved control over the quality of workmanship and over inspection.

The basis for predicting competitive power generation costs from a modular power plant (including those with multiple nuclear modules supplying a single turbine-generator) is that the balance-of-plant is largely freed from safety requirements, and that the repetitive shop fabrication of identical modules will reduce costs. Considering that the balance-of-plant accounts for roughly 80% of the cost of a conventional nuclear plant, the potential for savings by construction to commercial, rather than nuclear standards, is obvious. Both the commercial BOP and the repetitive shop fabrication will significantly reduce construction span, important to reduce escalation and interest charges now accounting for about 50% of a utility's investment, and to permit more accurate projections of load growth.

In summary, information cannot now be provided that a modular HTGR is a beneficial method of power generation, although preliminary studies indicate that this will be the case. A test program is required to verify the safety-related performance, a program which will also provide essential cost experience. Although the test article may have some salvage value if it survives the test, this cannot be assured. This is clearly an appropriate subject for Government funding, and provides the necessary and sufficient basis so that all subsequent activities can be handled by the private sector.

Question: What institutional impediments do you anticipate for small, modular nuclear reactor facilities, including both standardized reactor and balance-of-plant?

The modular HTGR program, in particular the version described in the previous answer, should eliminate the institutional impediments, rather than the reverse.

o There is a clear-cut and unambiguous demarcation between what the Government should do (the prototype safety tests) and what the private sector should do (all subsequent activities).

o Uncertainties over NRC requirements will be greatly reduced, allowing the equipment suppliers, the architect-engineers and the utilities to make rational commercial decisions. Furthermore, the projected costs of component fabrication and facility construction can be based upon experience, and the open-ended risk of some unforeseen technical problem will not be a factor. These are essential requirements for any business decision involving millions of dollars.

o Assuming that the safety tests have satisfied most of the critics, the risks of interventions and legal delays will be eliminated.

o Since an inherently safe reactor will be much simpler and less demanding to operate, the criticality of operator selection, training and testing will be reduced.

o The flexibility to select a plant with an appropriate number of modules to meet the requirements of each utility reduces the need for multiple ownership of plants, which sometimes proves troublesome. Smaller plants will place smaller demands on the dependence of the utility on the financial markets.

Question: In terms of weight and physical dimensions, what is the largest size reactor that could be manufactured in a shop and shipped to the field?

The Combustion Engineering shop and dock facilities at Chattanooga, Tennessee, have a rated maximum lift capacity of 800 tons, and the shop door is 35 feet, 6 inches wide by 42 feet high. Any single assembly fabricated within the shop building which is within these limits can be handled without facility modifications or special equipment.

As a point of reference, the largest single vessel considered to date in conceptual design studies for modular HTGRs is the lower vessel for the very high temperature methane reformer study. This vessel is 22 feet in diameter, 64 feet, 6 inches long, 8-3/4 inches thick, and weighs 840 tons. The design study was not constrained to stay within the nominal list capacity weight limit. The difference is small enough so that we believe it could be handled with special procedures or equipment. For the near-term steam cycle, cogeneration application, the weight is considerably lower because the lower temperature permits a thinner wall of 6-1/4 inches.

Shipments from the Chattanooga facility of assemblies of this size normally commence by barge. The largest barge that has been used has a capacity of 3000 tons. There is a fixed span bridge over the Tennessee River at Scottsboro, Alabama, with a height of 56.4 feet above the normal elevation of the river. This establishes a limiting restriction to the physical dimensions of shipments from Chattanooga.

With respect to overall transportation to a site, size limits are a function of destination. If the site is adjacent to navigable water, the limiting dimensions are those associated with inland waterways, and determined by existing equipment, generally 52 feet in diameter and 123 feet in length. If reaching the site entails overland transporation, the general, problem free limitations by regular railroad or highway would be about 15.5 feet in diameter and 70 feet in length. In both cases the particular geographic situation could influence capabilities and choice of transportation modes significantly. As an example, the Palo Verde vessels and steam generators were 23 feet and 25 feet in diameter, respectively.

Weight limitations of 800-900 tons would apply to rail shipments; water and highway situations would tolerate over 1,000 tons.

GAS-COOLED REACTOR ASSOCIATES
10240 Sorrento Valley Road STE. 300
SAN DIEGO, CA 92121
(619) 455-9500

Chairman

April 10, 1984

Hon. Marilyn Lloyd, Chairman
Subcommittee on Energy Research
and Production
U.S. House of Representatives
Committee on Science and Technology
Room B-374
Rayburn House Office Building
Washington, D.C. 20515

Attn: Ms. Debbie Martin

Dear Mrs. Lloyd:

I welcome the opportunity to expand upon and clarify my remarks made before your subcommittee by answering your questions of March 20, 1984. I apologize for the late reply, but my duties have frequently taken me from my office over the last few weeks. I hope my attached response is not too late to be of value. If you have additional questions, please feel free to contact me.

Sincerely,

R. F. Walker

R. F. Walker, Chairman
Gas-Cooled Reactor Associates, &
President & C.E.O.
Public Service Co. of Colorado

MLB:RFW:rcw

Enclosures

Q.1 Would you comment on the current institutional arrangements for nuclear plant design and construction? In particular, as President and CEO of Public Services of Colorado, wouldn't you rather look to one firm, and presumably the reactor manufacturer, for a 100% complete operating plant with a 5-year or 160,000 MW-hour guarantee, than have to coordinate with a reactor vendor, an A/E and a turbine manufacturer? It seems to me the current practice seems to place the responsibility for the design, construction and performance on the user.

A.1 All other things being equal, your suggestion of having one firm provide a complete operating plant with a solid warranty would be highly desirable, especially if that firm were to carry the financing through start-up. It is recognized that the smaller-size plant concepts, like the modular HTGR, potentially increase the possibilities of such a vendor/customer relationship developing to that extreme. In any event though, a decision by a utility to construct a nuclear power plant in the future will require a greater sharing of the risk by a vendor/industrial team that provides the plant. In addition, because of the uncertainty created in the past by changing regulations, the government will have to provide a more stable environment or also share some of this risk.

Regardless of the construction arrangements adopted in the future, the ultimate responsibility for design, construction and performance should be that of the user even if this responsibility manifests itself only in the form of providing user requirements, preferences, and supervision. In spite of the significant number of recent nuclear plant construction difficulties, there have also been a significant number of successes, and a common element to these successes appears to be a strong utility leadership intimately involved in the effort. Even in a scenario of warrantied "turn-key" construction practices, a close working relationship must exist among the user, vendor and regulator to ensure that the plant will meet appropriate requirements and that its costs will be well controlled.

Q.2 What market potential has been identified for the 100MWe and 425MWe reactor designs which you mention in your testimony?

A.2 The motivation for evaluating these smaller reactor designs stems not only from government interest and recommendations from institutions of learning and R&D, but also from the insistence of our own utility constituency. This utility interest in smaller plant sizes is evident in the results of the recent GCRA Summary Report of the Utility Questionnaire, where a preference was expressed for plant sizes in the range of 400 to 700 MWe and 200-400 MWe.

Not enough time has elapsed since this interest materialized to permit quantifiable market analysis. Nonetheless, the same GCRA survey revealed that, in spite of the present dirth of new plant orders and frustration with over capacity, utilities anticipate baseload capacity additions in the mid-to-late 1990's, and into the future. These small-sized HTGRs potentially could provide a portion of these baseload capacity additions, as well as replacement for baseload nuclear, coal and oil/gas-fired generation being retired.

The small-sized HTGRs represent a smaller more acceptable financial investment risk, especially in a period of high interest rates and relatively slow rates of load growths. These smaller plants represent smaller cash flows during construction and a better match to incremental growth in demand. The inherent ability of these smaller plants to incorporate passive heat removal to minimize the reliance on active engineered safeguards for safety and investment protection, to maximize factory fabrication, and to reduce the fraction of the plant that must be licensed as nuclear and maximize the use of non-nuclear construction practices results in plants that represent safer investments and greater licensing certainty. In addition to these less easily quantifiable attributes discussed above, preliminary analyses have shown that the smaller plants result in improved economics for smaller utilities, especially if constraints are placed on the utility's financial health, e.g., coverage ratios and construction-work-in-progress, during construction.

It should be noted that these advantages of smaller plants are offset by the adverse unit cost impacts of economy of scale, to a degree not yet determined. It is likely that the overall advantage of smaller plants will be a function of the utility's size, rate of load growth, the cost of money, and so on, resulting in markets for plant sizes ranging from a few hundred megawatts to over 800 MWe.

Q.3 How would you suggest selling the "Inherent Safety" concept to utilities and to the American public?

A.3 All HTGR concepts are characterized by unique features that distinguish them from the current generation of nuclear power systems. The most notable of these features is the inherent safety and low environmental impact characteristics that translate to less reliance on engineering safety systems, added margins for meeting certain licensing criteria, added margins for plant investment protection, greater siting flexibility, and reduced radiation exposure of plant personnel. It is these advantages on which to base acceptance of the HTGR by the utilities and the American public.

The 2240 MWt HTGR is a viable candidate for acceptance as a future commercial option. It embodies the above HTGR advantages that could lead to enhanced public acceptance and greater licensing certainty, as well as investment protection. By reducing the size and the power density, however, the degree of reliance on engineered safeguards can be further reduced by virtue of a greater reliance on passive heat removal under accident conditions. As the plant gets smaller, the reliance on engineered safeguards can be first minimized for meeting safety requirements, followed by a minimization of reliance on engineered safeguards for enhancing investment protection. The ultimate goal could be an HTGR that would be totally passively cooled for both safety and investment protection under all credible accident scenarios.

However, it should be realized that increased reliance on passive heat removal, requiring smaller core sizes and power densities, results in higher unit costs, perhaps to an unacceptable degree. Therefore, overselling "inherent safety" could be self defeating if the resultant product is not economically competitive. The goal of the HTGR Program should be to capitalize on its inherent safety features to more simply meet the NRC's safety requirements with high certainty while providing economic, reliable nuclear power.

Q.4 To what extent has the Nuclear Regulatory Commission been involved in the operation of the Ft. St. Vrain installation and subsequent HTGR studies?

A.4 While in the early licensing stages the NRC addressed Fort St. Vrain (FSV) as an HTGR, for the on-going licensing activities, FSV has been and is basically treated by the NRC as an LWR, with few exceptions. Failure by NRC to recognize the unique HTGR features of FSV and the practice of applying LWR regulations and criteria have resulted in an extra burden of time and special communications, verbal and written, to resolve issues. This special effort could and should be removed for future HTGR licensing activities by developing licensing criteria specific to the HTGR. Otherwise, a prejudicial application of LWR licensing precedents could lead to a non-economical HTGR design. Failure to resolve critical licensing issues creates a barrier to a commitment to build an HTGR because they introduce an uncertainty as to the ability to license a new concept within a given schedule. Barriers can be minimized by a licensing process which provides for an early design approval, prior to construction commitment, and by a top-down development of criteria which consider the unique characteristics of the HTGR.

To date, there has been little NRC involvement in the HTGR Program. However, on November 15, 1983, the Commissioners were briefed by HTGR Program participants on the status of the HTGR Program and safety characteristics of the HTGR. Subsequent to that briefing, the NRC began work on developing a regulatory policy for advanced reactors which specifically recognizes the need for special attention to the HTGR. Further, the NRC Research Program achieved a major milestone recently by completing a multi-laboratory assessment of the anticipated or potential radiological releases that could result from severe accidents in large HTGRs. This study provides a preliminary, but nonetheless comprehensive, basis for evolving criteria which recognize the inherent safety features of the HTGR.

As we have recommended to the respective Congressional Committees with NRC oversight, the NRC Program should expand its efforts to develop the criteria and bases for licensing HTGR plants, as well as supporting any Fort St. Vrain licensing development issues. The NRC Program should focus on (1) the development of NRC positions on procedural matters, technical approaches and data requirements pertinent to the pre-construction approval of an HTGR design; (2) the establishment of general design criteria and siting criteria specifically for gas-cooled reactors; and (3) the development of HTGR-related code cases and technical positions. In this latter area, in support of the evaluation of smaller HTGR plants, it would be particularly instructive if the preliminary assessment of potential radiological releases from HTGRs completed last year was amended to consider the inherent advantages of the smaller core sizes. The above effort should, of course, be coordinated with the DOE-funded HTGR development activities to assure the efficient use of national resources. Further consideration should also be given to expanding cooperative efforts with the Federal Republic of Germany and Japan.

Westinghouse
Electric Corporation
(202) 833-5076

1801 K Street N W
Washington D C 20006

April 9, 1984

Ms. Debbie Martin
Subcommittee on Energy Research
and Production
Room B-374 Rayburn House Office Bldg.
Washington, D. C. 20515

Dear Ms. Martin:

Attached are the supplemental questions which you submitted to Dr. Arnold late last month. We are pleased to respond to your request for additional information.

Sincerely,

David C. Shoaf
David C. Shoaf
Director
Advanced Energy Programs
Government Affairs

Attachment

RESPONSES OF DR. HOWARD ARNOLD
TO ADDITIONAL QUESTIONS FROM THE
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
COMMITTEE ON SCIENCE AND TECHNOLOGY

APRIL 9, 1984

Q1. Dr. Arnold - You propose as a new initiative the continued improvement of LWRs. The Department's budget proposal contains no funds for LWR research and development. Who do you propose should fund these R&D activities?

A1 The R&D actions that were suggested as necessary elements of light water reactor programs for the future should be funded by combined government and industry support. This would accomplish both involving the government in helping to address fundamental areas required for resurgence of the nuclear industry, and would demonstrate industry's willingness to meet new groundrules required for revitalization in the light water reactor market.

Q2. In looking at this problem of designing breeder reactors for the future, what do you consider to be the most important features that future breeders must have in order to meet market demands?

A2. For any reactor type to meet market demands, it must be cost competitive with existing power plants and provide low financial risk. For a breeder plant to be cost competitive, the plant fuel cycle cost, installed capital cost, and operating costs collectively must be equal to or, preferably, less than those for competitive power plants. The breeder reactor is different from other reactors in that it breeds its own fuel. However, it cannot achieve low fuel costs unless the bred fuel is inexpensively reprocessed. This requires that the fuel cycle be "closed." The approach Westinghouse has been pursuing is to integrate the fuel processing into the reactor plant so that the cycle is closed on-site. This provides a low fuel cost while eliminating all concerns about fuel shipment. In addition, integrated fuel processing reduces financial risk by assuring a continuous supply of fuel that is insensitive to the external availability or costs of fuel. The Westinghouse plant concept also incorporates its own radioactive waste disposal system, in which all high level waste is solidified in glass logs. These logs can be stored on site for a long period of time; although it is preferable to ship the waste to a repository. Low level waste is similarly treated.

While integrating fuel processing into the reactor plant can achieve a low fuel cost and greatly reduce the costs and social concerns associated with fuel shipment, it could have an adverse impact on plant capital cost. This has not been the case with the Westinghouse liquid metal plant design. Due to the unique design of the reactor containment building, simplification of systems, greatly simplified buildings and structures, and more efficient construction techniques, the overnight capital costs for the Westinghouse design are expected to be comparable to LWR costs.

Operating costs for the breeder reactor plant are expected to be competitive with those of coal plants and LWRs. The Westinghouse design achieves competitive operating costs through the use of maintenance and operating features which assure that the plant can be operated with a minimum of attention. For example, while the buildings are smaller than conventional plant buildings, there is, nonetheless, greater access for maintenance functions in the Westinghouse plant design.

Ultimately, the Westinghouse breeder plant design is projected to be cost competitive with existing power plants. It can achieve low fuel cycle costs due to integrated facilities. Through a unique arrangement and simplified construction, capital costs are expected to be within the competitive range, and simplified operation and maintenance ensure that operating costs will be similar to those for existing reactors.

A number of interrelated issues are involved in obtaining low financial risk for a future breeder plant. These include a short, predictable construction schedule, ease of licensing, and assured plant safety. A short, predictable construction schedule requires a short, standardized licensing procedure which in turn is likely to be more confidently obtained if inherent safety features are included in the plant design. A predictable construction schedule is also enhanced by design simplification and by use of many shop prefabricated building structures and components which reduce site construction time.

During plant operation, low financial risk is achieved through high reliability and operability, which is enhanced by the use of simple systems and components, ease of maintenance, and proof testing of key features. Eliminating the possibility of accidents which can lead to extensive downtime and repair is another key to low financial risk. Avoidance of severe accidents is assured if the plant safety features can maintain near normal conditions for components if low probability events should occur. Therefore, the use of passive, inherent features to shutdown and cooldown the plant will increase confidence that large financial losses will be avoided.

The Westinghouse concept uses passive safety features in many applications to reduce financial risks. For example, decay heat is removed by redundant natural circulation cooling loops with no requirement for electrical power or operator action. Also, while reactor shutdown is achieved in conventional ways, an increase in reactor temperature above the Curie point of the connecting magnet will drop the shutdown rods into the core. This system cannot in any way be disabled from functioning.

Additional inherent safety features are present in the design. The thermal capacity of the low pressure sodium coolant provides a long time delay for increasing temperature so that no single accident can uncover the core; thermal expansion of the reactor components reduce the power levelto near decay heat levels; and the entire system is naturally cooled to a safe temperature level by conduction and radiation of heat from the reactor vessel.

In summary, we believe that the Westinghouse liquid metal plant design concept incorporates many features that lead to low capital cost and low financial risk: Innovative plant design, integration of fuel processing and waste disposal into the plant, and extensive use of inherent safety features available within a liquid metal reactor concept.

Q3. Do you expect that there will be changes in the nature of the market for nuclear power plants? For example, do you see a retention of demand for large gigawatt-size plants as compared to smaller, compact reactor designs?

A3. Westinghouse sees the nuclear market coming back at two different megawatt sizes. The small plant (approximately 600 megawatts electric) would be the right size to meet immediate demands of small utilities while at the same time remaining highly competitive against coal and more competitive than oil. Other utilities (large utilities and small utilities willing to venture ahead with other small utilities) can and will continue to take advantage of the benefits associated with scaling nuclear plants to larger sizes. Although there is some disagreement as to how much can be gained by going to the gigawatt-sized reactors, there is little disagreement among knowledgeable individuals that reducing generation costs per kw-hr can be obtained by larger plants. Also, several key utilities already have good operating experience with larger units and, therefore, their willingness to consider large units would probably continue.

Q4. At our hearing, Dr. Behrens of the Congressional Research Service discussed his work on the economics of small reactors. Do you see markets for such reactors? Would there be cost advantages to small (100 MWe to 400 MWe) breeder reactors?

A4. A market for small reactors in the United States may exist as I identified as an answer to question 3. However, Westinghouse studies indicate that reactors below the 400 to 500 MW range may not be competitive with coal no matter what type of plant (LWR, HTGR, etc.) or the amount of modifications incorporated into these plants. Therefore, plants of the order of 100 MW will be extremely difficult to build and operate in a manner that can be demonstrated to be cost effective.

Q5. We have been emphasizing the need for inherent safety and low capital costs for future nuclear power plant designs. How are you addressing these features in your reactor design work?

A5. With regard to our pressurized water reactors, both inherent safety features and low capital costs are being addressed in our current advanced pressurized water reactor (APWR) design. This plant is leading us to the conclusion that both goals can be accomplished with the current light water reactor technology. As a point of information, and in contrast to other "paper studies", detailed design work and extensive testing have gone on and will continue to go on to verify that the APWR design meets the inherent safety and capital cost objectives. Note also that many of the features that have led to inherent safety and low capital costs on the APWR can be incorporated into pressurized water reactors at lower power levels.

With regard to our breeder reactors, the answer to question 2 addresses the features we used to obtain low cost and inherent safety.

Q6. In your testimony, you emphasize the utility problems which are related to predictability of acceptable cost and licensability. In testimony which we received earlier, this subcommittee was advised that the overriding problem is the lack of public acceptance for nuclear energy. What can you offer as an improved Light Water Reactor design which will not only answer utility problems, but also enable utilities to convince the public that the nuclear option is desirable and beneficial?

A6. It is important to realize that many of the primary issues facing the nuclear power industry are not public perception related. Current public perception has come about because of the actions of those organizations involved in nuclear power (utilities, lending institutions, etc.). The issues that must be addressed in order for utilities, public utility commissions, and state and local government to have confidence in nuclear power are reduction in the risk associated with nuclear power plant construction, and secondly, the need to simplify licensing of nuclear units without reducing public safety. Neither of these issues are being addressed by the current funding identified in the DOE budget. If these issues are addressed, public perception will also be significantly improved.

Using again the advanced PWR Westinghouse is currently designing as an example, significant improvements in public risk can be achieved. The net result is that Westinghouse has taken significant strides to improve the overall safety of the public. These improvements have been verified using risk assessment technology. None of the plants currently being considered by Congress for funding can improve significantly on public safety beyond the advanced PWR.

Q7. What opportunity for success could you anticipate for a small, standardized nuclear reactor offered to the utility industry in our current regulatory environment?

A7. As identified previously, Westinghouse believes that there may be a domestic small plant market in the future. How large this market will be, is difficult to estimate because very few utilities are considering any form of new generation capability at this time. However, the Westinghouse two-loop (650 MWe design) has been and could be implemented quickly, efficiently, and cost effectively in the U.S. if a standard plant approval were provided by the NRC and a utility would commit to building this plant. Under these circumstances, Westinghouse could build this unit in the United States in approximately six years.

In addition, after some additional development effort is completed, we believe that the Westinghouse liquid metal plant design concept described in response to question 2 will also prove to be cost effective as a small, standardized plant.

R. O. Williams, Jr.
President

Energy Systems Group
Rockwell International Corporation
8900 De Soto Avenue
Canoga Park, California 91304

(818) 700-3201

Rockwell
International

March 30, 1984 In reply refer to 84ESG-1682

Honorable Marilyn Lloyd
Chairwoman, Subcommittee on Energy
Research and Production
United States House of Representatives
Committee on Science and Technology
Suite 2321, Rayburn House Office Building
Washington, D.C. 20515

Dear Representative Lloyd:

I wish to thank you again for the opportunity to testify at your February 8, 1984, subcommittee hearing on the Department of Energy's budget request for Fiscal Year 1985.

The enclosure to this letter contains my answers to the questions regarding nuclear energy and nuclear reactor designs which you requested in your letter of March 20, 1984.

Sincerely,

R. O. Williams, Jr.

0058w/srs

Enclosure as noted

Enclosure

ADDITIONAL QUESTIONS FOR MR. WILLIAMS

Q: In looking at this problem of designing breeder reactors for the future, what do you consider to be the most important features that future breeders must have in order to meet market demands?

A: To penetrate the market, breeder reactors must provide (1) energy costs competitive with other electrical production sources, (2) safety (based on passive, inherent characteristics) that stabilizes the licensing process and promises protection of investment, (3) "friendliness" to user--such as ease of operation, low exposure levels for plant personnel and confidence in reliability and safe operation of components and systems. In addition, in the current environment of low-capacity growth and high finance charges, the breeder designs and supporting development must provide flexibility to meet the users' needs as they emerge. Eventually, we must standardize plant designs for economics and short licensing and construction schedule.

Q: Do you expect that there will be changes in the nature of the market for nuclear power plants? For example, do you see a retention of demand for large, gigawatt-sized plants as compared to smaller, compact reactor designs?

A: Over the long term, with possible moderate-to-high growth rates in electrical demand, large base-loaded electrical plants will probably be needed for minimum cost of power generation. In periods of slower growth and higher interest rates, and particularly in the current environment which is beset by many complex problems, it is possible that generating plants in which small-capacity modules are added may best satisfy electrical growth needs at acceptable financial risk. This approach, however, incurs larger initial energy costs and greater total capital costs. Close examination of specific needs must be made before the most favorable approach can be determined.

Q: At our hearing, Dr. Behrens, of the Congressional Research Service, discussed his work on the economics of small reactors. Do you see markets for such reactors? Would there be cost advantages to small (100 MWe to 400 MWe) breeder reactors?

A: Dr. Behrens' study was very interesting, and there may well be markets for such reactors. One assumption made in Dr. Behrens' study introduces significant uncertainties in his conclusions. He assumed only a 12% unit capital cost difference between 400-MWe and 1200-MWe units, whereas our studies of breeder reactors indicate the cost difference will be substantially larger. Also, as he states at the outset, joint ownership of plants was not addressed and would tend to favor the economics of the larger plants. It is recognized, however, that there also have been several bad experiences with jointly owned plants.

Q: We have been emphasizing the need for inherent safety and low capital costs for future nuclear power plant designs. How are you addressing these features in your reactor design work?

A: Rockwell International has pioneered the effort to capitalize on the inherent safety of sodium and the ability to minimize construction quantities and capital costs in liquid metal power plants. This pioneering work was done under company funding starting in the 1970s, and currently is being funded by DOE. We are cooperating with Argonne National Laboratory and have the support of Combustion Engineering and Bechtel Group, Inc., in this effort. Our designs emphasize localizing systems upon which plant safety depends, eliminating plant safety dependency of balance-of-plant systems, relying on passive cooling systems, structural redundancy, inspectable/monitorable structures and systems, core configurations with inherently low energetics, and design configurations in which inherent reactivity feedback is such that the plant shuts itself down even under loss of flow--plant blackout conditions with failure to scram. We further are capitalizing on aerospace methods to provide assured plant reliability and diagnostic capability. We will be pleased to discuss details of this sodium-cooled reactor design at your convenience.

MINORITY QUESTIONS

Q: To what extent do you believe the inherent safe reactor concept can be applied to processes beyond the liquid metal-cooled reactor process?

A: The inherently safe features incorporated in our liquid metal reactor design and under development and demonstration in the U.S. and overseas cannot be applied to LWRs. The basic inherent safety concept can perhaps be employed successfully in small HTGRs--but the economic viability of this concept is unlikely, as evidenced by the abandonment of gas-cooled reactor programs both in the U.S. and overseas and by the Fort St. Vrain experience.

Q: What assurances can you provide to a utility customer to enable him, in turn, to convince the public that any nuclear reactor is a beneficial source of electric energy?

A: Assuming a strong supporting development program and successful dialogue with the NRC, it should be possible to offer credible assurances of the breeder plant qualities described under the first question, i.e., competitive energy costs, inherent safety, and user friendly. Compared with alternate sources of electrical energy, nuclear and particularly breeder reactors have outstanding safety records and are environmentally much cleaner. Studies by the National Academy of Engineers, the Electric Power Research Institute, and the U.S. Department of Energy all point to nuclear and coal as the only practical energy sources within reach for meeting future electrical requirements. The World Health Organization and the American Medical Association have both identified reactors as the safest form of energy production. However, considerable reformation of domestic licensing/construction/design practice is needed, and institutional adjustments are necessary to fully exploit the benefits of nuclear power which are now being realized overseas.

GENERAL ELECTRIC
GENERAL ELECTRIC COMPANY
175 CURTNER AVENUE
SAN JOSE, CALIFORNIA 95125

DR. BERTRAM WOLFE
VICE PRESIDENT AND GENERAL MANAGER
NUCLEAR FUEL AND SPECIAL PROJECTS DIVISION

March 27, 1984

The Honorable Marilyn Lloyd, Chairman
Energy Research and Production Subcommittee
House Science and Technology Committee
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Mrs. Lloyd:

I appreciate the opportunity to supplement the record of the hearing with responses to questions included with your letter of March 20, 1984. While I plan to respond to each question, the following is a preliminary answer to the three questions Mr. Milder noted to be particularly urgent.

- WHAT FEATURES OF YOUR MODULAR BREEDER DESIGN CONTRIBUTE TO INHERENT SAFETY AND REDUCE THE CAPITAL COST OF CONSTRUCTION?

Our concept for reactor self protection includes three principal features. First, the power level has been set and the nuclear heat supply assembly has been designed so that shut-down heat removal can be accomplished without pumps, valves or any external connections to the assembly. Since the containment is only slightly larger than the reactor vessel, our concept relies on thermal radiation between the reactor and containment vessels and natural convection of air over the containment to maintain the shut-down temperature at a safe, non-damaging level. Second, it is expected the relatively small modular reactor can be designed so that a loss of coolant flow without scram would not result in major damage to the nuclear heat supply assembly. We expect this can be accomplished by taking advantage of the potential negative reactivity temperature coefficient of the small core and by designs that enhance control rod drive thermal expansion as well as enhanced thermal expansion of the core. Third, the close coupling of the containment vessel prevents loss of coolant in the event the reactor vessel is breached. These and other features, once proven, could conceivably result in the nuclear heat supply being the only nuclear grade assembly in the power production loop.

These enhanced safety features, combined with the small size of the modular reactor, will allow us to take full advantage of the higher productivity of factory production over field construction. We believe a complete nuclear heat supply assembly can be factory produced, assembled quality-assured and shipped to the site for installation in a biological shield. We intend to review all systems and subsystems of the modular reactor for potential factory assembly and shipment to the site. We believe this approach can be applied to much of the secondary loop and steam generator and possibly many of the auxiliary and feedwater systems. Obviously the lower the power level, the smaller the assemblies and the greater the potential for prefabrication. We believe the combination of increased factory production of assemblies and non-nuclear standards for the balance of plant could offset the diseconomy of scale normally associated with small nuclear assemblies.

- HOW WOULD AN ADVANCED BREEDER FUEL CYCLE R&D EFFORT, SUCH AS THE BRET PROGRAM, IMPACT YOUR DESIGN?

No liquid metal reactor, including our modular reactor, can be considered a competitive alternative to other power production means until its fuel cycle is closed and demonstrated to be economic. This involves fuel fabrication, fuel life, fuel recycle and waste processing operations. Demonstration of fuel performance has dominated the nation's fuel program and it is generally accepted today that satisfactory breeder fuels can be produced. However, the economics of fuel recycle, fabrication and the performance of recycled fuel involve uncertainties that must be resolved.

The BRET program is applicable to our modular reactor reference core. BRET can provide data on the recovery and recycle of fissile material from oxide fuels and could significantly reduce the cost of this operation. One major item would be an evaluation of relaxed impurities specifications and the effect this may have on the recycled fuel performance. The BRET program will also provide a firmer basis for design and assessment of the economics of commercial facilities.

- AT OUR HEARING, DR. BEHRENS OF THE CONGRESSIONAL RESEARCH SERVICE DISCUSSED HIS WORK ON THE ECONOMICS OF SMALL REACTORS. DO YOU SEE MARKETS FOR SUCH REACTORS? WOULD THERE BE COST ADVANTAGES TO SMALL (100 MWe to 400 MWe) BREEDER REACTORS

Small reactors may play an important part in a future utility environment requiring smaller increments of added nuclear capacity. This may occur due to electrical growth rates and the need to reduce financial risks. It is an area that clearly requires study. It has been ten years since the industry has examined new small reactor designs for the U.S. However, we believe development of this market requires concepts that overcome the diseconomy of scale normally associated with small reactors and demonstrations of the cost and technical features of such concepts.

It is not possible to make a meaningful determination of the cost of small breeder reactors at this time although initial estimates for our liquid metal modular reactor are quite encouraging. However, there are unresolved issues with the modular breeder. These include: the economics of the fuel cycle, regulatory acceptance of reactor self protection concepts, other known technical challenges involving the details of design and those that will develop with further study. These issues will require time and effort for resolution. We believe this effort is worthwhile for, despite the uncertainties, the modular reactor may offer the only practical approach to development of a U.S. breeder reactor as well as a possible means of regaining a position among the leaders of the international breeder development effort. The high costs of constructing a series of medium-to-large size developmental plants makes this traditional approach highly unlikely of success in today's U.S. environment.

General Electric is appreciative of your continuing efforts in support of the nation's nuclear program. I trust the above and my March 20, 1984 letter to you will be of value in this important initiative. We will continue to support you in any way we can in this matter.

Very truly yours,

Bertram Wolfe

Bertram Wolfe

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue, Argonne, Illinois 60439
Telephone 312/972- 4863

March 28, 1984

Marilyn Lloyd, Chairman
Subcommittee on Energy
Research and Production
U.S. House of Representatives
Committee on Science and Technology
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Madam Chairman:

I very much appreciated the opportunity to testify before your Subcommittee on February 8, 1984. I enclose answers to the supplemental questions you sent me in your letter, dated March 20, 1984. I regret that I was unable to respond within the five days you requested in your letter as it reached me too late to do so.

I hope the answers provide you with the information you wish. If I can clarify any points further, I would certainly be pleased to do so.

Sincerely,

C. E. Till
Associate Laboratory Director
Reactor Research & Development

CET:vag
Enclosure

U.S. Department of Energy The University of Chicago

1. *In looking at this problem of designing breeder reactors for the future, what do you consider to be the most important features that future breeders must have in order to meet market demands?*

Breeders designed for the future must demonstrate specific capability for resolving modern concerns about the breeder, and more generally, about nuclear power as a whole. Not all of these concerns had even been identified, or in retrospect, given due emphasis, when the basic directions of breeder development were set two decades ago. Indeed, the make-or-break importance of features that answer these concerns is only slowly coming to be recognized at the present time.

Non-proliferation and Diversion Resistance have come to the forefront only in the past decade. Plutonium Supply for initial fueling was not considered to be any problem a decade ago, when LWR fuel was to be routinely reprocessed. Inherent safety as opposed to "Engineered Safeguards" was given little weight, until the TMI-2 experience indicated its desirably. Reduced Capital Costs, at least for the initial breeder plants were until recent years given little weight. It was assumed that the breeder would be coming in rapidly and in large numbers so that evolutionary improvements would bring costs down sufficiently. Waste was assumed to be taken care of by augmentation of LWR reprocessing and waste storage operations that would already be in place. A Closed Fuel Cycle was also assumed to follow naturally from the LWR Purex-based reprocessing operations that would be in place. Finally, the limiting effect on Realistic Breeder Deployment of the need for very large sizes for Purex-based reprocessing (to allow reasonable fuel cycle economics) was not foreseen because the present strenuous opposition to unrestricted fuel transport has not yet begun to appear.

Any one of these may well be sufficient to make breeder reactors impractical if the breeder design of the future does not have features that address them satisfactorily. They are therefore the features that I believe time will show to be necessary for breeder designs of the future.

2. *Do you expect that there will be changes in the nature of the market for nuclear powerplants? For example, do you see a retention of demand for large gigawatt-size plants as compared to smaller, compact reactor designs?*

In the long term I think it is inevitable that the magnitude of demand, the technology improvements from continued development both in operational and cost performance, and the reality of scale economics will combine to make large reactor sizes the choice for most electrical load. However, without a short term there will be no long term. In the short term, it is equally obvious that the magnitude of the financial risks associated with present-day large reactors have destroyed their marketability. As there is no market for large reactors today, specific development of smaller sizes, particularly if capacity can be added incrementally to hold initial financial risk to manageable levels, may very well be the way to make nuclear power viable again. At worst, there is little to lose. Today it is not a case of choosing between two viable options, one large and the other small incremental. No large plants are being ordered, and there is the possibility that if they are the only option, the hiatus might become permanent.

3. *How much money has been spent on your IFR program, and are there funds for this work in the FY 1985 budget request?*

There are really two answers to this question. The IFR as a specific concept as yet has had very little spent on it. The IFR (and other preliminary concept work) is funded by DOE under the "Concept Studies" activity in the base program at Argonne, currently at a level of 600K for FY 1984. Prior to FY 1984, Large Pool Plant (oxide-fueled) concept development was the focus. In this fiscal year DOE encouraged our focus on compact plant studies, which led to the IFR concept. This far into the fiscal year, about 200K has been spent on the IFR itself.

Looked at from another angle though, the IFR has had the benefit of very substantial experience and expenditures over the years. As you know, the Argonne base breeder program is unique in the completeness of its range of breeder development activities. Reactor physics, reactor safety, core design, components development, breeder power reactor operations (EBR-II) are all centered here, and the main expertise in metallic fuel fabrication, performance, and reprocessing, along with the necessary hot-cell capabilities remain here as well. The ideas, and evidence for feasibility, of the IFR came from this base program. It is impossible to do financial accounting on this type of thing, but as an example, EBR-II has operated for 20 years using a metallic fuel closely related to that proposed for the IFR, irradiating hundreds of thousands of metallic fuel pins. EBR-II itself costs about $20 million per year, in current dollars, including its experimental program. So from this viewpoint, the IFR has had substantial development work and expenditures associated with it.

The current FY 1985 President's budget does not have explicit funding for the IFR. I am aware that DOE is in the process of recasting the budget, and I am optimistic that the IFR will be taken into account in some fashion. I have no reason to believe, however, that DOE will find it possible to fund the IFR at the levels I believe are necessary for the development program to go forward in a priority manner.

4. *What are you suggesting, from an R&D aspect, that this Committee should do regarding the IFR?*

I believe that the IFR has the potential to answer each one of todays concerns about the breeder. The concept has precisely the features I noted as being necessary in my answer to a previous question. In this it is unique.

But the IFR is a concept at this point, not a proven design. There is technical evidence supporting the basic feasibility of every element of it, but in several areas the evidence is not yet sufficient. Development work has to be done. It is a fortunate fact that the nation at the present time still has precisely the right human resources in terms of expertise and experience, and also precisely the right facilities in operation to do this development and demonstration relatively cheaply. This is unlikely to be true for long, for a number of reasons. Not the least important of these is that much of the expertise resides in people nearing the end of their professional careers. If the promise of the IFR is to be pursued, it is important that it begin now.

IFR development requires about $35M in each of FY 1985 and FY 1986, over and above the present Argonne base breeder program budget of $70M annually, to prove feasibility in two years. (Substantial amounts of the $35M would be spent other than at Argonne, but the present Argonne budget gives a reference point.) In the three years after proof of feasibility, comparable annual expenditures would be necessary, leading to a full-scale demonstration of the concept in a modified EBR-II complex, fully operational as a prototypic IFR in five years from the present time. Additionally, the EBR-II Integral Fuel Cycle Facility would have sufficient inherent capacity built-in naturally, to fuel, without modification, a CRBR-size demonstration plant if it were then seen as desirable to proceed.

I believe the combination of IFR features, the relatively inexpensive development, and the clear path that can be seen to its demonstration, make the benefit-to-risk extraordinarily high. Because I believe it must be undertaken quickly, or it will not be possible at all, I ask the support of the Committee in enabling us to do so.

5. *Are there reasons to use metal fuels over oxide fuels in breeders?*

As a broad statement, once the burn-up problem that blocked earlier development of metal fuels was solved, metallic fuels bring a variety of potential advantages to sodium-cooled breeder design. Each, of course, has to be taken advantage of by the specific design. The basic single technical reason that terminated metallic fuel development in the 1960's was that metallic fuel of that time would burn up only to about 1% before swelling and bursting the clad, and there was no known way around this. This problem has now been solved. Tens of thousands of metallic fuel pins have been burned up in EBR-II to 8-1/2% or more without failure. (The current goal burn-up for new EBR-II fuel is 14%.)

The advantages of metallic fuel come across the board.

Operationally, this fuel is extraordinarily robust. At the same normal operating power as oxide it will take at least three times as much over-power before onset of melt. It also handles transients (surges in power) very easily, as the fuel puts very little mechanical stress on the clad.

It has unique and well-defined inherent safety characteristics, we believe, superior to any other fuel. In addition to its superior operational margins, which beneficially affect safety, it appears to have inherent properties that act in serious accident situations to cause very strong self-shutdown mechanisms to come in, first, before any core damage can occur, and again before any accident could progress to the point the public could be affected. When combined with a pool design, for example, a metallic-fueled fast reactor will shut itself down from full power if the coolant pumps go off, even if the control rods do not go in, with no damage whatsoever to the core or anything else. These potential properties are unique to metal fuels, and they are potential huge advantages.

Metallic fuels also bring with them the possibility of maintaining the metallic form throughout the reprocessing and refabrication steps of the fuel cycle. Because the density of metal is so high, the volumes that need to be handled are extremely small -- a teacup a day for a CRBR-size plant. Everything becomes small and compact, with the corresponding potential for cost reduction in buildings, equipment, and so on.

The fabrication of metal fuel is also extraordinarily simple. Only a casting process where a hundred or so pins are cast at a time, then clipping to length, sliding them loose-fit into the clad with a small amount of sodium bond, and welding the top. The process is cheap and easy. It is used routinely in EBR-II fuel fabrication.

Metallic fuel reprocessing can take place immediately upon removal of spent fuel from the reactor. Nothing in the process is damaged by intense radiation, so no long cooling time is necessary. This means that the spent fuel can be turned around and back into the reactor in a period of weeks, if desired. Thus very little fuel is ever outside the reactor, so a large (and costly) fuel inventory waiting to be reprocessed is not required. Also, the fuel can stay highly radioactive at all times as a further deterrent to diversion.

Finally, metal fuel can be designed to be a superb breeder, if desired. The physics properties of metal fuel give them the highest possible potential breeding of any fission reactor system, with all the implications for long-term energy supply that this implies. On the other hand, they also makes the design very flexible. Today's IFR concept is designed to be just self-sustaining. The tradeoff in breeding is taken in economic advantages.

In summary, there is no one advantage that would make the case alone that metallic fuel should be preferred. In total though, I believe metallic fuel has a massive advantage.

6. *What amount of work has been spent to date on the Integral Fast Reactor concept? This includes the amount of money spent, the number of people involved, the extent of hardware investigation, and the extent of industry involvement.*

The answer to this question in large part is contained in my answer to the previous similar question. The element I did not touch on was industry involvement. This has been substantial. Remarkably so for the short time that has elapsed since the IFR was proposed a couple of months ago. First, Argonne has an on-going co-operative conceptual design activity for the IFR with an industrial group composed of Rockwell International, Combustion Engineering, Chicago Bridge and Iron, and the Bechtel Group. Second, we have been exploring with General Electric the possible adaptation of the IFR to their modular breeder concept. Finally, we are working out arrangements with Westinghouse for cooperation on their Compact Integral Breeder design, and it is my present understanding that they would like to adopt the metallic fuel cycle for this plant, although discussions are still at an early stage.

7. *Through what program do you propose to carry this IFR concept forward to proof of concept? What cost would you estimate for the design and construction of a pilot facility?*

The answer to this question also is largely contained in my response to a previous question. In the interest of clarity, however, I will summarize again here. We propose proof-of-concept in two years, by the end of FY 1986. At this time the key experiments, the conceptual design both of the reference IFR plant, and the required modification to the EBR-II complex will be complete. The operating funding requirement is about $35M for each of FY 1985 and FY 1986.

The next step is to provide full-scale demonstration in EBR-II (essentially converting it to an IFR prototype). The modification to the EBR-II complex for the Integral Fuel Cycle Facility is a relatively minor upgrade of the existing facility and equipment design and installation. The estimated costs -- very rough at this time -- are in the range of $50M, but these would be firmed up in the two-year proof-of-feasibility period, before submitting any formal request. This then would be the cost of "design and construction of a pilot facility".

8. *The IFR concept is much more comprehensive in scope than any other reactor concept presently active. What barriers would you anticipate in promoting this concept?*

The barriers, I suppose, are the same as for any new concept proposed in an established area with an established infrastructure. First, the need for the new concept must be recognized and accepted. Second, the fact that is is new by its nature means that everything has not been proven and it is therefore more speculative than its established competition. Third, new concepts cause institutional changes that can be uncomfortable. Fourth, funding for development is limited and work on a new concept probably means less work on others. Finally, assuming all of the above are addressed satisfactorily, the technical issues must be addressed by a dedicated, expert group of scientists and engineers with the motivation and drive to carry the development through successfully.

The last point is not a trivial one. There is enough capability left today so that this can still be done, but today's environment does not make it easy. I believe it will become even more difficult if things go on as they are. Quite simply, reactor development needs new promise to attract and maintain first-rate technical capabilities. I believe the IFR provides such promise.

INTERNATIONAL
ENERGY
ASSOCIATES
LIMITED

March 30, 1984

Ms. Debbie Martin
Subcommittee on Energy
Research and Production
Room B-374
Rayburn House Office Building
Washington, D.C. 20515

Dear Ms. Martin:

In response to Chairman Lloyd's request, I am providing answers to additional questions on the PIUS reactor, supplementing my testimony of February 8.

Sincerely,

John C. Young

JCY/cec

enclosure

2600 VIRGINIA AVENUE, N.W.
WASHINGTON, D.C. 20037
202 - 342 - 6700
Telex 89-2680 Cable IEAL WASHDC

- In a July 1983 report prepared by the Institute for Energy Analysis, the design of a PIUS (Process Inherent Ultimate Safety) reactor was described as being one that does not require, "all the usual quality assurance standards and any requirements for redundancy, diversity and separation should not be due to nuclear safety considerations, but are warranted only on the basis of cost-effectiveness. The result is an enormous simplification in plant design." Would you explain what that means in terms of public safety?

The PIUS reactor design involves inherent safety strategies which differ from the LWR safety criteria. The PIUS design includes inherent characteristics within the reactor system such that failures within the reactor system will initiate a natural system response toward a safe condition. This approach allows safety to be achieved with fewer reactor and plant systems. All parties (utility company, NSSS supplier, AE, constructor, and the NRC) can focus their efforts in these fewer systems areas. This does away with a major problem in the present LWR program. That problem is the enormity of systems and components which require detailed safety examination in the design, construction and operation of LWRs. These "add-on" safety systems of the LWRs are what make the LWRs so complex, particularly with their associated quality assurance requirements. These systems would not exist in PIUS.

In terms of public safety, the PIUS reactor and the LWR are the same, because the NRC performs a satisfactory job in maintaining LWR public safety. In terms of cost to obtain public safety and to protect the reactor owner from economic loss of plant due to TMI-type accidents, the PIUS reactor is far superior.

- To what extent has the Nuclear Regulatory Commission reviewed the PIUS reactor program? If they had been involved, what response have you received to date?

ASEA-ATOM has provided the NRC staff, the Commissioners, and the Advisory Committee on Reactor Safeguards (ACRS) information on the PIUS design and the PIUS development program. ASEA-ATOM has met with the NRC staff for discussion on the PIUS design and has made formal presentations to the full Commission and the full ACRS. The Commission has encouraged ASEA-ATOM to proceed with further development and to provide additional information as it becomes available. At its February 27, 1984 Commission meeting on advanced reactor regulatory development, the Commission indicated it would be assessing the PIUS reactor along with the LMFBR and the HTGR.

- What do you believe to be the economical size or sizes for the PIUS reactor concept?

The ASEA cost analysis for PIUS is under review by TVA at this time. Such a review will provide a better insight into PIUS economics. ASEA believes PIUS will be economic in a size range from 400 MWe to 800 MWe. ASEA further is examining the economic potential in sizes below 400 MWe, with a view toward third world country roles. The cost savings in PIUS include the potential for reducing the large physical security forces associated with U.S. reactor plants.

- What responses have you received from the PIUS concept in your discussions with American utilities?

The introduction of the PIUS concept to American electric utilities has just begun; however, the response and interest level have been excellent. The Tennessee Valley Authority (TVA) has cooperated extensively with ASEA-ATOM in conducting a review of the PIUS design and the cost estimate, as well as conducting some independent R&D in the thermal/hydraulic area. International Energy Associates Limited (IEAL) has discussed the PIUS concept with a limited number of utility companies, regarding the possible formation of a PIUS reactor utilities group to perform continuing reviews and assessments of the PIUS development program and to introduce the various utility company perspectives and views as potential owner/operators. The response to this informal inquiry has been favorable, including expressions of interest to join such a utility review group and also to examine the reasons behind the successful ASEA-ATOM LWR experience.

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
1400 WILSON BOULEVARD
ARLINGTON, VIRGINIA 22209

28 March 1984

Ms. Debbie Martin
House Committee on Science & Technology
Subcommittee on Energy Research & Production
Washington, D.C. 20515

Dear Ms. Martin:

Thank you for the letter of 20 March 1984, which forwarded additional questions to supplement the record of the 8 February Hearing on DOE's FY1985 Budget request.

Attached are the six questions and responses which have been prepared for inclusion in the record.

If I can be of any further assistance, please contact me at (202) 694-1703.

WEWright
William E. Wright
Director, SP-100 Program

Attachment
as

Q: What is the situation regarding DOD interest in multi-megawatt space power systems? Will there be a proposal for funds for such a system before the Armed Services Committee this year? If so, would such an endeavor come under the management control of the SP-100 program?

Dr. Wright: The Strategic Defense Initiative (SDI) proposal now before the Armed Services Committee contains the DOD FY85 funding for both the multi-megawatt and 100 kilowatt class technologies. The budget submission has a total of $11.0M for DOD in FY85 of which $8.0M is for the 100 KW class program which is currently underway and which has been described to you. The additional $3.0M is to begin a long range technology program suitable for the high power systems required for the SDI. The 100 KW class system would support SDI requirements in the areas of surveillance, tracking, designation, and housekeeping as well as non-SDI military, civil, and commercial missions. The multi-megawatt technology program, which will not enter into development of a specific system until at least the 1990's, is primarily focused on SDI space weapon and surveillance requirements, but could also support civil missions of the more distant future. In order to ensure complete coordination, the Department of Defense has designated the SP-100 organization to manage all parts of this effort.

Q: Is the $350 million figure a total multi-year figure or an annual figure for FY 1986?

Dr. Wright: The $350 million is for the entire period FY86 through FY91. This funding level will support a minimum version of the engineering development and ground test phase and will lead to a follow-on flight application phase.

Congressman Young: In January, I participated in the Space Nuclear Power Systems Symposium in Albuquerque. Dr. Mark of NASA spoke eloquently on the future potentials of the space station. What sort of activities could be undertaken on future space stations that would need the power levels from space reactors?

Dr. Wright: Development and growth scenarios for the space station are being laid out now by NASA. They show a rapid increase in required power levels from less than 100 KW when first deployed to over 300 KW within the first ten years. This growth in power demand comes principally from manufacturing and housekeeping requirements. Examples of the manufacturing activities responsible for these projected power requirements are zero gravity crystal growth and pharmaceutical manufacturing of items such as growth hormone and beta cells for treating diabetes.

Congressman Young: I noticed that there were a lot of industry and university people at that symposium. This tells me that there is considerable interest in the space reactor program. Are there sufficient funds available within the program to justify this interest and accommodate the involvement of all the capable players?

Dr. Wright: While we have taken pains to identify and bring into the program the most experienced and talented of the nuclear power and space communities, it is certainly not possible to accommodate all the capable players at this stage in the program. The previous US space nuclear power program which spawned the many organizations and individuals with experience and capability in the field was very large. It pursued a multiplicity of reactor and conversion concepts through lengthy development programs. Our current program is an attempt to establish feasibility at substantially higher performance levels than the prior program; as such it is currently an order-of-magnitude smaller than the previous program. In the next phase it is our intent to develop only one technology into a system and test it, so that our program will still involve fewer institutions and individuals than before. Therefore, while there are certainly going to be greatly expanded opportunities for the most capable, we will not be able to involve everyone. Long range multi-megawatt technology work and peripheral activities, such as an expanded long-term technology base program, could partially relieve the situation.

Q: There has been a significant period of time from the previous space nuclear power programs to the present time. Where did the information on that technology reside and what difficulty have you had in bringing it up to date?

Dr. Wright: We found two basic sources of information. The first consisted of documentation and technical reports in a number of corporate, government, laboratory, and personal libraries across the country. This has largely been retrieved and identified. The second source was the large number of experienced individuals — scientists, engineers, and managers — who were involved with the program until 1972, when it was terminated. Many of these are still with the same companies and institutions while others have moved on and contacted us once they heard about SP-100. All of this past information is integrated into our current design concepts and test programs. We are reaching well beyond the past work in our performance requirements, which are driven by the emerging missions. We have had almost no difficulty in bringing the data up to date since almost no new work of even the most fundamental nature has been done for the last 10 years in the field.

Q: Is all of the multi-megawatt initiative of the SP-100 program classified?

Dr. Wright: The multi-megawatt portion of SP-100 will support the Strategic Defense Initiative almost exclusively. We are now in a planning exercise to define the FY85 program. The intent of the planning process is to identify those technologies which, in the long run, could contribute the most toward meeting the emerging SDI mission requirements. These mission requirements and the resulting power level and run time system requirements are obviously classified; therefore, we are keeping our current planning activities largely classified. However, once the program is completely defined in the next few months, we would expect that most of the technology development activities can be decoupled from the specifics of the missions and therefore will be unclassified. Only those few pieces of the program intimately linked to weapons applications (such as technologies for hardening against threats) or which offer breakthrough potential for military mission performance will be classified.

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

June 6, 1984

ES-NP-84-551

US House of Representatives
Committee on Science and Technology
Room B-374 Rayburn House Office Building
Washington, D.C. 20515

Attention: Ms. Debbie Martin

In response to questions regarding my testimony on February 8, 1984, during the Subcommittee's hearing on the Department of Energy's budget request for FY 1985, I submit the attached material. If I may be of further assistance to the Subcommittee, I will be pleased to do so.

Sincerely yours,

Jay E. Boudreau
Deputy Associate Director
for Nuclear Programs

JEB:pa

Attach: a/s

NUCLEAR FISSION HEARING - FEBRUARY 8, 1984

1. Question: Very early in your testimony, you refer to compact reactors. Please describe the size of these reactors relative to electrical output. It would be helpful to describe the probable configuration, or configurations.

   Answer: The size of each of the several classes of reactors discussed throughout the testimony is as follows:

   a) Defense Terrestrial Reactor (DTR) - The nominal size for this system is 10-MWe. The configurations under consideration will be proprietary, and are anticipated to use proven technologies. For example, concepts such as the following could be proposed:
      - A power TRIGA with a Freon power conversion system
      - A sodium cooled system
      - Pressurized water reactor

   b) North Warning System (NWS) - At present, we are considering 15-kWe systems for short-range radar applications; long-range applications may require powers of the order of 350 kWe. We are considering a design which utilizes a graphite fueled and heat-pipe cooled reactor whose power conversion is achieved by either thermoelectrics or organic Rankine cycles.

   c) SP-100 and Multimegawatt Systems - Two principal 100-kWe systems remain under consideration. One is a thermionic system using diodes similar to those developed by General Atomic, Inc. in the 1970s. The other design employs a more traditional oxide fuel element design that has some similarity to that developed for breeder reactors. Both systems are liquid metal cooled. Design details for the multimegawatt systems are not yet determined, and will likely be classified.

2. Question: You describe a market survey in which you have become involved.

   - Please provide for this Committee a copy of the directive which initiates this activity.

     Answer: See Attachment A, which is a work scope describing the work. (There is no "directive".)

   - The amount of funding necessary.

     Answer: $450,000.

   - The source of those funds.

     Answer: The US Department of Energy, Office of Nuclear Energy.

   - Qualifications of those persons making this market survey.

     Answer: See Attachment B.

   - The extent of interface with this steering group.

     Answer: Los Alamos asked a group of senior people from the financial and industrial sectors to serve as consultants on the study. The interface has been one session to review methodology and another session is scheduled to evaluate preliminary study findings.

- Past examples of similar activity.

Answer: Many market studies have been conducted by the Laboratory or others in the past. Studies of nuclear energy supply and regulation are fairly common. Attachment C cites examples of other studies conducted by Los Alamos. However, a market study of the type alluded to in testimony before the Committee may be unique in one regard. In this study, we are looking at energy, supply needs for specific energy and centers rather than the more traditional reliability regions. We feel this approach may lead to different conclusions than those from previous studies.

- Any other information which might justify this activiy.

Answer: I feel that energy security in the US remains an important issue, both for the health of our society and economy and for National Security (defense) reasons. An important contribution can be made by nuclear power. Nontheless, the overall need for nuclear power in this country is masked by near-term economic and sociopolitical factors. It is essential to examine whether legitimate near-term markets and needs exist to warrant continued Federal support of the nuclear option. I feel that such needs may, in fact, exist and that sound policy making requires that information be available to DOE, the Congress, and others if we are to make wise decisions. It is in this spirit that the study is suggested.

3. Who requested that Los Alamos submit a program plan through DOE on the construction of a prototype reactor unit in five years for the DTR program?

   Answer: The request was from the Assistant Secretary for Defense Programs, DOE.

4. Who designated Los Alamos to manage the DTR program and select these design proposals?

   Answer: Los Alamos has not been designated to manage the DTR Program, nor has Los Alamos been designated to select the design. DTR management will be executed between DOE and the Air Force. The eventual role of Los Alamos on the DTR Project is not yet determined. A DOE Source Evaluation Board will be established to evaluate proposed designs.

5. What is the nature of the Air Force participation in this program?

   Answer: As part of its energy security program, the Air Force is assessing the feasibility of using existing small-scale reactor technology for secure electrical power supplies. At the present time, the Air Force has provided no funding for the DTR program; it has reviewed a Feasibility Study made by Los Alamos. Arrangements between the Air Force and DOE are still being developed.

6. To what extent have the selection criteria been developed for these design proposals?

Answer: A Commerce Business Daily announcement has been prepared and a statement of work for the RFP has been drafted. Both items address selection criteria, which will include topics such as plant cost, plant reliability, safety, etc. These documents are being held for release prior to final approval of FY-1984 DOE funding of the Program.

7. What is the nature of the interaction between Los Alamos, DOE, the Air Force and related agencies like the State Department and NRC for both the DTR Program and the North Warning System Program?

Answer: The interaction between the Los Alamos, DOE, and the Air Force is in its early stages for both the DTR and North Warning programs. For DTR, DOE is providing technical guidance and the Air Force is providing guidance on Air Force needs. Because of the early status of the programs, it is premature to involve either the State Department or the NRC.

8. Is all the multimegawatt initiative of the SP-100 program classified?

Answer: It is our understanding that the initiative is classified Secret due to its close interaction with specific strategic defense initiative requirements. We expect that much of the actual technology work will be unclassified. It is my understanding that classification guidance is of an interim nature, and formal classification guidance is under review. Our present guidance is defined in Attachment D.

ADDITIONAL QUESTIONS FOR DR. BOUDREAU

1. What is the funding split between the defense program and the civilian program support for your compact reactor work?

Answer: Funding available in FY-1984 for Defense Terrestrial Reactors is anticipated to be $2M; funding for the North Warning System is anticipated at $895K.

For the North Warning System, $895K is in hand. $400K of this funding is from DOE/DP and $495K is from the Air Force.

No funding is anticipated in FY-1984 from DOE/NE for DTR or NWS.

The FY-1984 internal Los Alamos funding for SP-100 is $4.4M. This program has both civilian and defense components.

There is no funding, at this time, for the multimegawatt program.

FY-1984 funding for compact civilian nuclear power work at Los Alamos centers around modular breeder reactors, and is about $600K.

Question: Is there some sort of cooperative funding arrangement?

Answer: For the Space Reactor Program, there is a cooperative funding agreement between DARPA, DOE, and NASA (see Attachment E). It is anticipated that DOD and DOE will cosponsor some additional amount of work in the near future. For DTR, as mentioned earlier, all projected funding at this time is from DOE. For the North Warning System funding, there is cooperative funding between DOE and the Air Force.

Question: Is DOD involved in a direct way, or is this all DOE-supported work?

Answer: DOD is involved in a very direct way. A multimegawatt planning effort is underway by DOD and DOE. The Air Force Weapons Laboratory's Space Technology Center with two other Air Force organizations, has also participated. No funding has been made available thus far, however.

2. What are the generic features of the compact reactor designs under study at Los Alamos that are attractive from a civilian applications perspective?

Answer: Coincidentally, all of the reactor concepts have in common

- Inherent safety
- Factory fabrication
- Standardization
- High reliability
- Minimal operator training needs
- Competitive cost
- Minimal time for deployment

This response refers to DTR and the North Warning System. Space Reactor Programs are sufficiently different in character that their application to civilian terrestrial needs is not as direct.

3. Will the remotely-sited reactors for the Air Force be cost-competitive with alternate sources of power, such as diesels or fuel cells?

Answer: Preliminary work to date indicates they are cost-competitive. For North Warning, it appears that although reactors have a higher initial cost, their life cycle costs are less than diesels and fuel cells.

Attachment A: Funding guidance for market study

Attachment B: Los Alamos economic staff

Attachment C: Economic studies by Los Alamos

Attachment D: Classification guidance letter from D. Krenz

Attachment E: Three-party MOU, SP-100

DOE F 1325.8

United States Government | Department of Energy

memorandum

Albuquerque Operations Office

Attachment A

DATE JAN 31 1984

REPLY TO ATTN OF: ETD:RLH(0894)

SUBJECT: Small Reactor Power Systems

TO: K. D. Lathrop, Associate Director for Engineering Sciences, LANL

Thru: H. E. Valencia, Area Manager, LAAO

The attached January 20, 1984 DOE HQ message, Chipman/Romatowski, requests that LANL add to its ongoing breeder market survey a task to conduct a technological and commerical assessment of reactor power systems in the small to intermediate size range. Funding is to be provided as specified in the message.

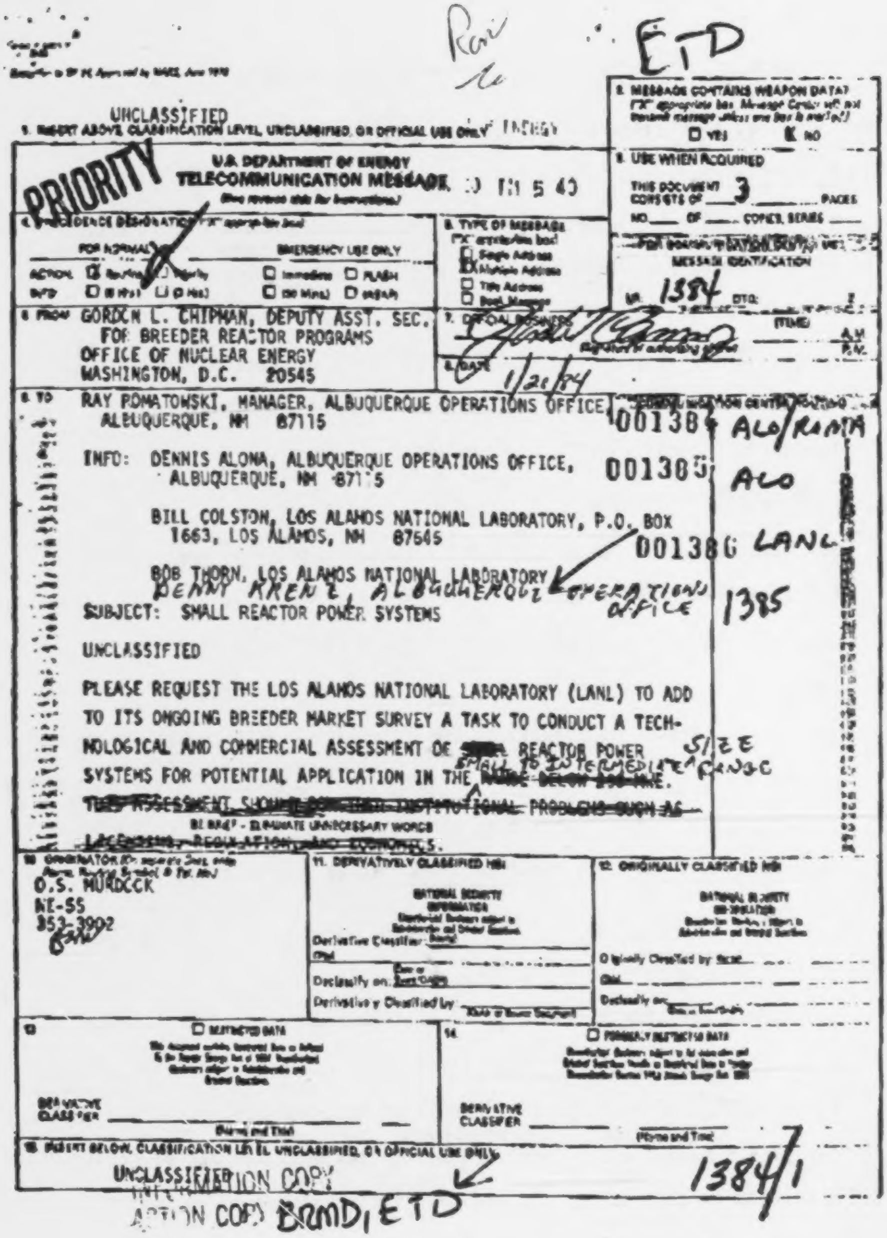
Please note that the obligational authority and cost ceilings provided in this authorization are subject to the limitations provided in the Approved Funding Program (AFP). Accordingly, please determine your ability to meet the program objectives within the limitation of this authorization and AFP. Should the program objectives prove incompatible with the authorized funding levels and AFP, advise me of any required funding adjustments or those tasks which cannot be accomplished.

Dennis L. Krenz
Director, Energy
Technologies Division

Attachment

cc w/Att:
D. R. Ellis, BRMD, AL
L. A. Traver, FMD, AL
G. J. Garcia, BUD/B244, LANL
J. R. Ireland, QDO/K552, LANL
R. N. Thomas, DIR OFC, LANL
✓J. E. Boudreau, ES-NP/F671, LANL

cc w/o Att:
G. L. Chipman, NE-50, DOE HQ
B. W. Colston, ES-NP/F671, LANL



Rav
Ae

ETD

UNCLASSIFIED

1. INSERT ABOVE CLASSIFICATION LEVEL, UNCLASSIFIED, OR OFFICIAL USE ONLY ENERGY

PRIORITY

U.S. DEPARTMENT OF ENERGY
TELECOMMUNICATION MESSAGE 30 JN 5 40

2. MESSAGE CONTAINS WEAPON DATA? ☐ YES ☒ NO

3. USE WHEN REQUIRED
THIS DOCUMENT CONSISTS OF 3 PAGES

NO.____ OF ____ COPIES, SERIES ____

MESSAGE IDENTIFICATION
NR. 1384 DTG:

4. PRECEDENCE DESIGNATION ("X" appropriate box)
FOR NORMAL / EMERGENCY USE ONLY
ACTION ☒ Routine ☐ Priority ☐ Immediate ☐ FLASH
INFO ☐ ☐ ☐ ☐

5. TYPE OF MESSAGE ("X" appropriate box)
☐ Single Address
☒ Multiple Address
☐ Title Address
☐ Book Message

6. FROM GORDON L. CHIPMAN, DEPUTY ASST. SEC.
FOR BREEDER REACTOR PROGRAMS
OFFICE OF NUCLEAR ENERGY
WASHINGTON, D.C. 20545

7. OFFICIAL BUSINESS
Signature of authorizing official
(TIME) A.M. P.M.

8. DATE 1/20/84

9. TO RAY ROMATOWSKI, MANAGER, ALBUQUERQUE OPERATIONS OFFICE, ALBUQUERQUE, NM 87115 — 001384 ALO/RAMA

INFO: DENNIS ALONA, ALBUQUERQUE OPERATIONS OFFICE, ALBUQUERQUE, NM 87115 — 001385 ALO

BILL COLSTON, LOS ALAMOS NATIONAL LABORATORY, P.O. BOX 1663, LOS ALAMOS, NM 87545 — 001386 LANL

BOB THORN, LOS ALAMOS NATIONAL LABORATORY

DENNY KRENZ, ALBUQUERQUE OPERATIONS OFFICE — 1385

SUBJECT: SMALL REACTOR POWER SYSTEMS

UNCLASSIFIED

PLEASE REQUEST THE LOS ALAMOS NATIONAL LABORATORY (LANL) TO ADD TO ITS ONGOING BREEDER MARKET SURVEY A TASK TO CONDUCT A TECHNOLOGICAL AND COMMERCIAL ASSESSMENT OF ~~SMALL~~ REACTOR POWER SYSTEMS FOR POTENTIAL APPLICATION IN THE SMALL TO INTERMEDIATE SIZE RANGE ~~RANGE BELOW 250 MWE~~. ~~THIS ASSESSMENT SHOULD CONSIDER INSTITUTIONAL PROBLEMS SUCH AS LICENSING, REGULATION, AND ECONOMICS.~~

BE BRIEF - ELIMINATE UNNECESSARY WORDS

10. ORIGINATOR
O.S. MURDOCK
NE-55
353-3902

11. DERIVATIVELY CLASSIFIED NSI
Derivative Classifier:
Declassify on:
Derivatively Classified by

12. ORIGINALLY CLASSIFIED NSI
Originally Classified by
Declassify on:

13. ☐ RESTRICTED DATA
DERIVATIVE CLASSIFIER ____ (Name and Title)

14. ☐ FORMERLY RESTRICTED DATA
DERIVATIVE CLASSIFIER ____ (Name and Title)

15. INSERT BELOW, CLASSIFICATION LEVEL, UNCLASSIFIED, OR OFFICIAL USE ONLY.
UNCLASSIFIED

1384/1

INFORMATION COPY
ACTION COPY BRMD, ETD

-2-

1220784-

[redacted]

The technical evaluation will focus on three key tasks.

1. Historical Survey

The contractor will investigate, evaluate, and summarize past experience in developing and utilizing small and intermediate size power reactors. This evaluation will include civilian and, where practical, military applications. The existence of supportive research and development efforts, both Federally and privately funded, and design, construction, and operating experience will be considered.

2. Institutional Barriers

The contractor should evaluate the technology-oriented institutional barriers that would presently limit ~~the~~ realization of the full potential of small and intermediate size power reactors. This would specifically include an evaluation of alternatives to the present thrust of the licensing process towards requiring incremental design modifications and retrofits. This evaluation should assess the appropriate role and differences in constraints of the private versus public sector. This task should identify possible concept improvements or institutional arrangements to overcome the institutional constraints.

exist. regulatory in

3. Concept Evaluations, Applications, and Costs

The contractor should identify and analyze the technological concepts or options that appear to offer the most attractive features needed to promote user interest for these small or intermediate size reactors. This analysis should include incremental improvements/ ~~improved~~ reactor designs and methods of construction that both enhance safety and reduce life cycle cost. The contractor should seek to evaluate new and innovative concepts offered by reactor vendors.

84/2

THE TOTAL SCOPE OF THIS TASK IS ESTIMATED TO BE $1,500,000 WITH $1M PROVIDED FROM FY 1984 FUNDS AND $500,000 FROM FY 1985 FUNDS. ~~THE $1M~~ $950K FOR FY 1984 WILL BE INCLUDED IN YOUR ~~NEXT~~ FEBRUARY APPROVED FUNDING PLAN IN THE FOLLOWING B&R CATEGORIES:

	BA	BO
AE2020	$100,000	$100,000
AF1540303	300,000	300,000
AG2520	50,000[1]	50,000[1]
AS1525	50,000	50,000
AG3005	190,000	190,000
CD1001232	310,000	310,000
	$1,000,000	$1,000,000

[1] FUNDING ($50K) WILL BE TRANSFERRED IN MARCH AFP FOR B&R AG-25-20.

THIS IS A HIGH PRIORITY EFFORT AND LANL SHOULD BE ASKED TO IMPLEMENT IT AS EXPEDITIOUSLY AS POSSIBLE UNDER COMPETITIVE PROCUREMENT PROCEDURES, AS IMPLEMENTED BY THE LAB.

IN ADDITION, $75,000 IN BA AND BO WILL ALSO BE ADDED TO YOUR NEXT APPROVED FUNDING PLAN UNDER AF-15-40-3, GENERAL SUPPORT. THIS IS TO BE USED IN THE PHASE III AREA OF YOUR ONGOING BREEDER MARKET SURVEY FOR FINANCIAL, INSTITUTIONAL, AND REGULATORY ACTION PLAN DEVELOPMENT.

Attachment B

ECONOMICS GROUP STAFF

ECONOMISTS	9
COMPUTER MODELING	2
DATA ANALYSIS AND SUPPORT	4

EDUCATIONAL FIELDS

ECONOMIC THEORY	3
GENERAL ECONOMICS	2
MINERAL ECONOMICS	2
RESOURCE ECONOMICS	1
AGRICULTURAL ECONOMICS	1
MATHEMATICS	1
ASTROPHYSICS	1
SOCIOLOGY	1

DEGREE LEVELS

PhD	5
ABD	4
MS	2
BS	1

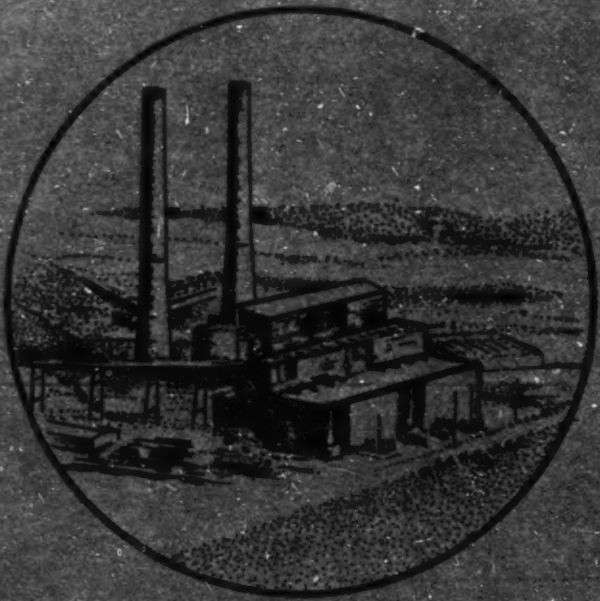
EDUCATIONAL FIELDS OF PRECEDING DEGREES IF OTHER THAN LISTED ABOVE

ENGINEERING PHYSICS, GEOLOGY, GEOCHEMISTRY, PHYSICS, AGRONOMY, MBA, CONSUMER STUDIES, COMPUTER SCIENCE

LALP-84-1

Attachment C

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.



Electric Utility Reports

Winter 1983

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

An Affirmative Action/Equal Opportunity Employer

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

CURRENT LOS ALAMOS STUDIES OF NUCLEAR ENERGY AND UTILITY ECONOMICS

LICENSING REFORM INDIRECT BENEFITS

ANALYSIS OF PHASE-IN SCHEMES TO MODERATE RATE SHOCK

CONSERVATION MODELING FOR BONNEVILLE POWER ADMINISTRATION

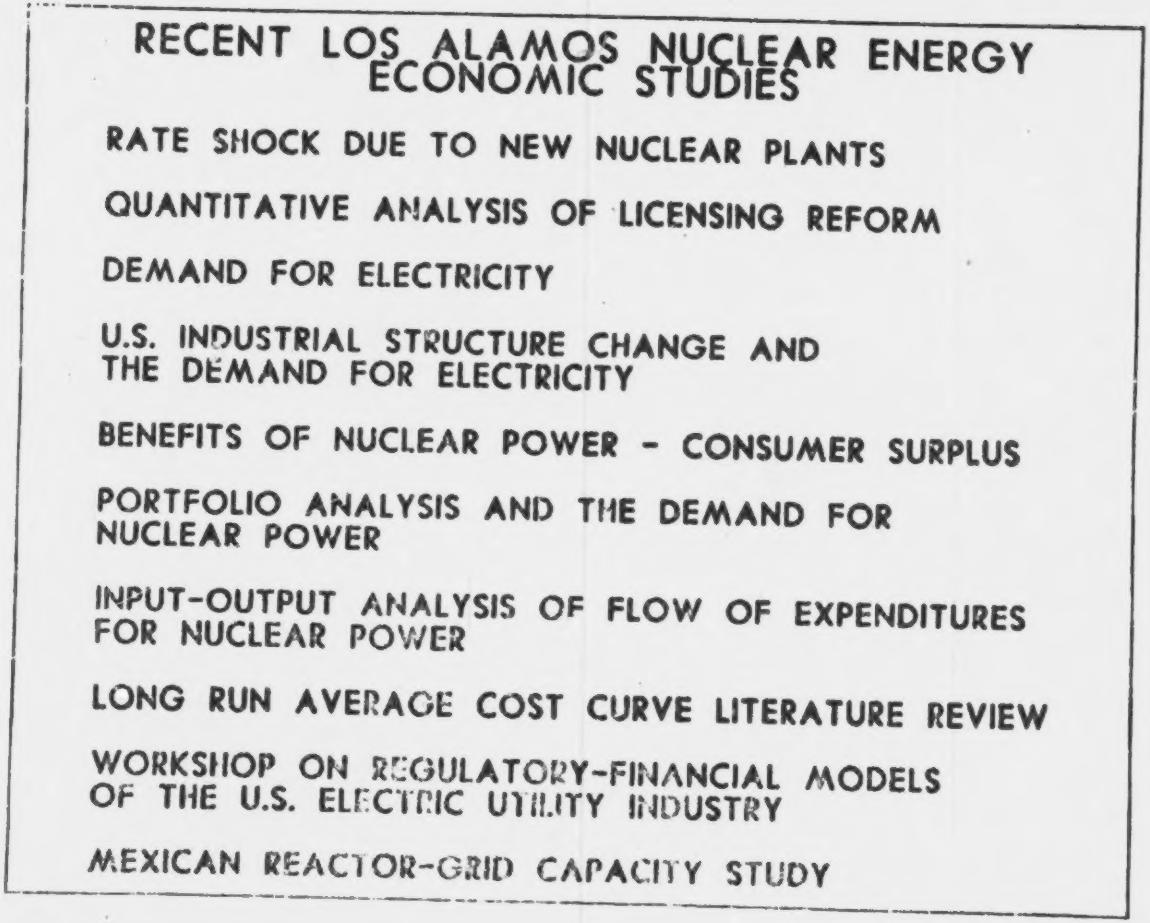
ROLE OF ELECTRICITY IN STIMULATING GNP (JOINT STUDY WITH NATIONAL ACADEMY OF SCIENCES)

LICENSING AND CONSTRUCTION MODELING FOR ELECTRIC POWER RESEARCH INSTITUTE

ASSESSING THE MARKET FOR NEW ELECTRIC GENERATING CAPACITY

ON-LINE LOS ALAMOS UTILITY ECONOMICS MODELING SYSTEMS

EPPAM	- ELECTRIC UTILITY POLICY AND PLANNING ANALYSIS MODEL
LACUMS	- LOS ALAMOS COAL AND UTILITY MODELING SYSTEM
PERT-Monte Carlo	- PROBABILISTIC PERT CHART ANALYSIS
POPCYCLE	- POWER PLANT LEVELIZED LIFE-CYCLE COSTS
BICYCLE	- GENERALIZED LEVELIZED LIFE-CYCLE COSTS
ALPS	- LINEAR PROGRAMMING SYSTEM FOR FORECASTING OPTIMUM ELECTRIC POWER GROWTH PATTERNS



RECENT LOS ALAMOS NUCLEAR ENERGY ECONOMIC STUDIES

RATE SHOCK DUE TO NEW NUCLEAR PLANTS

QUANTITATIVE ANALYSIS OF LICENSING REFORM

DEMAND FOR ELECTRICITY

U.S. INDUSTRIAL STRUCTURE CHANGE AND THE DEMAND FOR ELECTRICITY

BENEFITS OF NUCLEAR POWER - CONSUMER SURPLUS

PORTFOLIO ANALYSIS AND THE DEMAND FOR NUCLEAR POWER

INPUT-OUTPUT ANALYSIS OF FLOW OF EXPENDITURES FOR NUCLEAR POWER

LONG RUN AVERAGE COST CURVE LITERATURE REVIEW

WORKSHOP ON REGULATORY-FINANCIAL MODELS OF THE U.S. ELECTRIC UTILITY INDUSTRY

MEXICAN REACTOR-GRID CAPACITY STUDY

LALP-84-1

Issued: February 1984

Electric Utility Reports

Winter 1983

Andrew Ford
Ronald Sutherland

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

ELECTRIC UTILITY REPORTS
WINTER 1983

by
Andrew Ford and Ronald Sutherland

ANALYSIS AND ASSESSMENT DIVISION
MAIL STOP F605
LOS ALAMOS NATIONAL LABORATORY
P. O. BOX 1663
LOS ALAMOS, NEW MEXICO 87545

This bibliography lists reports and publications on electric utility issues written at the Los Alamos National Laboratory from 1976 through 1983. The theme of these publications is economic analysis, and most of the work was completed by the Economics Group (S-2). However, some related contributions from the Statistics Group (S-1) and Energy Technologies Group (S-4) are included.

Table I lists papers and reports involving simulation modeling of the regulatory and financial issues at individual electric utilities.

Table II lists papers and reports explaining the structure and applications of the Los Alamos Coal and Electric Utility Modeling System, which has been used to analyze industry issues at the regional and national levels.

Environmental constraints to electricity generation is the topic of the papers and reports listed in Table III.

Table IV lists our econometric studies of the demand for electricity and of the reliability of nuclear power.

Our economic studies of small versus large power plants are presented in Table V.

The final table (Table VI) focuses on the economics of nuclear power. Areas studied include proposals for reform of the nuclear power plant licensing process, costs and benefits of nuclear power, nuclear power plant reliability, and laser fusion.

The main sponsors of our work include
- Bonneville Power Administration (BPA)
- Department of Energy (DOE)
- Electric Power Research Institute (EPRI)
- Energy Information Administration (EIA)
- Environmental Protection Agency (EPA)
- National Commission on Air Quality (NCAQ).

We express our appreciation to the following groups with which we have collaborated in the execution of the research:
- Applied Energy Services, Inc.
- California Energy Commission
- Control Data Corporation
- Pacific Gas and Electric Company
- Stanford Research Institute
- Texas Center for Energy Studies
- University of California
- University of New Mexico.

For further information write to Barbara Lujan, Publications Department, Economics Group, Los Alamos National Laboratory, phone (505) 667-3816, FTS 843-3816. Or call Robert Drake, Group Leader, (505) 667-4442, FTS 843-4442.

TABLE I: REGULATORY AND FINANCIAL SIMULATION MODELING

DOCUMENT	DESCRIPTION
TECHNICAL DOCUMENTATION	
1. A. Ford and I. Yabroff, "Technical Documentation of the Electric Utility Policy and Planning Analysis Model," Los Alamos Scientific Laboratory report LA-7773-MS (June 1979), 74 pp.	Technical description of the EPPAM1 model including an overview of each sector; a discussion of the important loops and delays; and a listing of the base-case parameters, the computer equations, and the variable definitions. Several examples of model behavior are reported and analyzed.
2. I. Yabroff and A. Ford, "An Electric Utility Policy and Planning Analysis Model," SRI International final report (December 1980), 154 pp.	Technical description of the EPPAM2 and EPPAM3 models including overviews of each sector, DYNAMO flow diagrams, list of parameters, list of equations, and variable definitions. Several examples of model behavior are reported and analyzed.
3. A. Ford and A. Youngblood, "Technical Documentation of the Electric Utility Policy and Planning Analysis Model, Version 4," Los Alamos National Laboratory report LA-9347-MS (April 1982), 103 pp.	Technical description of the EPPAM4 model with emphasis on the changes from the EPPAM3 model. Major changes are the inclusion of conservation investments, improvements in the regulatory-financial sectors, and changes in the production sector.
SUMMARY DESCRIPTION	
1. A. Ford, "Using Simulation for Policy Evaluation in the Electric Utility Industry," *Simulation* (March 1983), 8 pp.	Briefly describes the EPPAM3 model along with simulation results dealing with oil backout and planning under uncertainty. Concludes with a discussion of model validity.
SENSITIVITY ANALYSIS	
1. A. Ford and M. McKay, "A Method of Quantifying Uncertainty in Energy Model Forecasts," Los Alamos National Laboratory document LA-UR-82-1423 (Summer 1981), 37 pp.	Demonstrates how confidence bounds on model forecasts may be established through the iterative application of Latin Hypercube Sampling and Sensitivity Analysis. A version of EPPAM3 adapted to serve as the electric utility sector of FOSSIL2 is the test model, and the model's forecast of oil and gas use in the nation's power plants is the variable of interest.
APPLICATIONS	
1. A. Ford and A. Polyzou, "Oil Backout and the Price of Electricity," *Energy, The International Journal* 7, No. 5 (1982), 20 pp.	Answers the question whether overbuilding to displace oil or gas burning plants will lead to lower or higher electric rates in the future. The EPPAM3 model is used to simulate the rate effect of overbuilding under a wide range of costs and circumstances.

TABLE I: REGULATORY AND FINANCIAL SIMULATION MODELING (CONT)

DOCUMENT	DESCRIPTION
2. A. Ford and A. Youngblood, "Simulating the Spiral of Impossibility in the Electric Utility Industry," *Energy Policy* (March 1983), 20 pp.	Uses the EPPAM3 model to simulate the severity of the so-called "spiral of impossibility" in which increasing rates depress demand causing utilities to request further rate increases to cover fixed costs. Results are presented for coal-dependent companies as well as for companies heavily dependent on oil or natural gas. Policies for countering the adverse effects of the spiral are tested with the model.
3. A. Ford and A. Youngblood, "Simulating the Planning Advantages of Shorter Lead Time Generating Technologies," *Energy Systems and Policy* 6, No. 4 (1982), 33 pp.	Uses the EPPAM3 model to simulate the advantage of investing in wind machines, geothermal stations, small coal plants, or other technologies with shorter lead times. The model's performance under unpredictable demand growth measures the benefits of shorter lead time plants. Also reviews the models and methods used in six studies of capacity expansion under uncertainty.
4. A. Ford, "Short Lead Time Technologies as a Defense Against Demand Uncertainty," to appear in *The Strategic Planning Process in Electric Utilities*, 25 pp.	Reviews the results of modeling studies to quantify the planning benefits of short lead time technologies when demand growth is highly uncertain. Discusses changes in risk when the firm switches to short lead time technologies.
5. R. Sutherland, "Penetration of Four Solar Technologies in Electric Utilities and the Environmental Benefits," Los Alamos National Laboratory report LA-9149-TASE (December 1981), 37 pp.	Estimates likely penetration of wind, biomass, photovoltaics, and solar thermal using the EPPAM3 model parameterized for 10 federal regions. Displaced coal and nuclear generation and the corresponding reduction in sulfur dioxide and oxides of nitrogen are also calculated for each region.
6. A. Ford, "Calculating the Cost Effectiveness and Limitations of Electric Conservation Subsidies," Los Alamos National Laboratory document LA-UR-83-1339 (May 1983), 37 pp.	Examines utility subsidies, which encourage customers to use electricity more efficiently, for cost effectiveness and total contribution to the resource plan. Presents illustrative results for the Pacific Gas and Electric Company.
7. A. Ford and S. Harris, "A Simpler Method for Calculating the Cost of Conservation Subsidies for an Electric Utility," to appear in *Energy Policy* (1984), 10 pp.	Presents a highly aggregated method of calculating the cost of conservation subsidies with a demonstration using the conservation programs of the Pacific Gas and Electric Company.

LOS ALAMOS WORKSHOP	
1. A. Ford and G. Mann, "Summary of the Workshop on Regulatory-Financial Models of the US Electric Utility Industry," Los Alamos National Laboratory report LA-9815-C (June 1983), 60 pp.	Summarizes the presented papers and group discussions among 40 individuals at a May 1982 Los Alamos workshop on regulatory and financial models.

TABLE II: LOS ALAMOS COAL AND ELECTRIC UTILITY MODELING SYSTEM

DOCUMENT	DESCRIPTION
TECHNICAL DOCUMENTATION	
1. F. Wolak et al., "Documentation of the Los Alamos Coal and Utility Modeling System, Version 3.0," Los Alamos National Laboratory report LA-8863-MS (May 1981), 38 pp.	Presents technical description and documentation of the LACUMS model including sample results and data base. LACUMS is a modeling software used for examining the effects of governmental regulations on coal-related industries. By altering the associated data base, a user can vary the focus of regional and technological detail and readily construct a model appropriate to a particular field of inquiry. Models utilizing the LACUMS software include the ROCKY models and EUFUM (Electric Utility Fuel Use Model).
2. R. Bivins et al., "ROCKY1: An Energy-Environment Model of Coal and Electricity Supply," Los Alamos Scientific Laboratory report LA-7988 (February 1980), 22 pp.	Provides background and technical description of the ROCKY1 linear programming model of coal and electricity supply. ROCKY1 is a predecessor to other models that are formulated with the LACUMS software. A particular focus of ROCKY1 is ambient air pollution regulations in the Western US.
3. C. Kolstad et al., "A Dynamic Linear Programming Model for Allocating Energy Supply Activities Within the Rocky Mountain Region of the United States," *Applied Numerical Modeling*, Pentech Press, London (1978), 14 pp.	Presents a conceptualization of a dynamic version of the ROCKY1 model.
APPLICATIONS	
1. C. Kolstad et al., "Oil and Gas Use by Electric Utilities in the Eighties," Los Alamos National Laboratory report LA-9319-MS (April 1982), 149 pp.	Presents a detailed analysis of oil and gas use by electric utilities through 1990. Projections are based on the Regional Reliability Council's announced construction plans. The Electric Utility Fuel Use Model, defined with LACUMS, was used for the analysis.

TABLE II: LOS ALAMOS COAL AND ELECTRIC UTILITY MODELING SYSTEM (CONT)

DOCUMENT	DESCRIPTION
2. C. Kolstad, "Effects of Accelerating the Construction of Nuclear Power Plants on Oil and Gas Use," Los Alamos National Laboratory report LA-9171-MS (December 1981), 15 pp.	Shows that accelerating construction schedules for nuclear power plants by up to two years could save an average of nearly 150 000 equivalent barrels per day of oil and gas over the decade of the 1980s.
3. C. Mangeng et al., "The Economics of Utility Oil and Gas Substitution: National and Region-Specific Analysis, Los Alamos National Laboratory report LA-9677-MS (February 1983), 46 pp.	Analyzes the effects of delays in power plant construction on oil and gas use by electric utilities and on electricity prices.
4. A. Bopp et al., "Air Quality Implications of a Nuclear Moratorium: An Alternative Analysis," *The Energy Journal* (July 1981), 19 pp.	Presents results of a ROCKY1 simulation of the effects of a moratorium on nuclear power in the US. In contrast to most other analyses, we find that significant increases in coal consumption by utilities do not necessarily lead to increased national sulfur emissions.
5. C. Kolstad, "Average Electricity Costs and Shadow Prices as a Function of SO_2 Standards for the Prevention of Significant Deterioration of Western Air Quality," Los Alamos Scientific Laboratory document LA-UR-79-1085 (April 1979), 21 pp.	Uses the ROCKY1 model and considers how strict air quality control in the Western US affects the price of electricity.
6. C. Kolstad and F. Wolak, "Competition in Interregional Taxation: The Case of Western Coal," *Journal of Political Economy* (June 1983), 29 pp.	Examines competitive taxation; focuses on Montana and Wyoming coal severance taxes. Concludes that monopoly rents are greatly reduced through competition, although significant rents still accrue.
7. C. Kolstad and F. Wolak, "Strategy and Market Structure in Western Coal Taxation," to appear in *Review of Economics Statistics*, 29 pp.	Analyzes the potential market power of western states in setting severance taxes. Also attempts to determine the emphasis that states place on tax revenues versus the economic development associated with coal mining.
8. C. Kolstad and F. Wolak, "On the Indeterminacy of Duopolistic Equilibria," Los Alamos National Laboratory document LA-UR-83-1034 (April 1983), 28 pp.	Analyzes the divergence of coal severance tax rates and tax revenues associated with a variety of models of duopolistic equilibrium.
9. C. Kolstad, R. Bivins, and R. Pendley, "Uncertainty and the Electricity Capacity Expansion Decision," presented at the 24th International Meeting of the Institute for Management Science, Honolulu, Hawaii, June 18-22, 1979, Los Alamos Scientific Laboratory document LA-UR-79-1688 (May 1979).	Considers some techniques for choosing mixes of technologies (coal and nuclear) based on uncertainty implicit in such choices.

TABLE III: ENVIRONMENTAL CONSTRAINTS TO ELECTRICITY GENERATION

DOCUMENT	DESCRIPTION
WATER AVAILABILITY	
1. D. Abbey, "Water Supply and Demand in an Energy Supply Model," Department of Energy report DOE/EV/10180-2 (December 1980), 54 pp.	Develops and documents the introduction of western water markets into the LACUMS framework. The approach allows the use of water conserving/cooling technologies in the energy sector. Water supply involves utilizing unallocated surface water, transferring water rights from agriculture, or pumping deep ground water.
2. D. Abbey and F. Lucero, "Water-Related Planning and Design at Energy Firms," Department of Energy report DOE/EV/10180-1 (November 1980), 34 pp.	Reviews engineering options and water use costs for energy facilities. Also presents survey data on water system design for electricity generating plants.
3. D. Abbey, L. Brown, and F. Roach, "The Role of Water in Energy Development," presented at the annual meeting of the American Association for the Advancement of Science, Washington, DC, January 1981, Los Alamos National Laboratory document LA-UR-82-674 (March 1982), 30 pp.	Studies demand for water in the Western US. While total water demand for energy over the coming decade seems large, it is shown to be fairly small in comparison with present irrigation use in the West.
4. V. Loose and D. Abbey, "Some Implications of Accelerated Synthetic Fuels Development in the Rocky Mountain States," Los Alamos Scientific Laboratory report LA-8588-MS (November 1980), 23 pp.	Uses a regionalized national energy model to examine the air quality and water quantity implications of accelerated synthetic fuels development.
AIR POLLUTION	
1. C. Kolstad, "The Four Corners Regional Study," Los Alamos National Laboratory document LA-UR-81-1537 (May 19, 1981), 47 pp.	Contains testimony presented before the Subcommittee on Health and Environment, US House of Representatives, summarizing work on a regional analysis of the Clean Air Act. The analysis considered the past, present, and future of the Act and its relationship to energy production in the Southwest.
2. C. Kolstad, W. Schultze, and M. Williams, "Clean Air and Energy: From Conflict to Reconciliation," submitted to Westview Press (January 1982), 20 pp.	Reviews some of the current and potential conflicts between energy development and air pollution regulations in the Intermountain West. A fairly simple analysis indicates that most of these conflicts can be resolved at moderate cost.
3. C. Kolstad, "Clean Air and Energy Reform of the PSD Provisions of the Clean Air Act," Los Alamos National Laboratory document LA-UR-82-3288 (September 1982), 34 pp.	An applied economic analysis of present and alternative air pollution regulations for achievement of ambient pollution concentration goals. Alternatives examined include emission fees, marketable emission permits, and technological standards.

TABLE III: ENVIRONMENTAL CONSTRAINTS TO ELECTRICITY GENERATION (CONT)

DOCUMENT	DESCRIPTION
4. C. Kolstad, "An Empirical Analysis of Regulatory Efficiency in Air Pollution Control," Los Alamos National Laboratory document LA-UR-81-1727 (November 1982), 37 pp.	An applied analysis of the prevention of significant deterioration of air quality focusing on the Four Corners Region. Examines emission fees versus marketable permits, spatial efficiency of controls, and command-and-control regulations versus economic incentives.
5. F. Roach et al., "Alternative Air Quality Policy Options in the Four Corners Region," *Southwestern Review of Management and Economics* (Summer 1981), 30 pp.	Presents a comprehensive analysis of potential changes in the Clean Air Act provisions for the prevention of significant deterioration of air quality. Examines alternatives to PSD from an economic (efficiency and distribution), political, and legal perspective.
6. C. Kolstad and M. Williams, "Simplified Source/Receptor Relations for the Economic Analysis of Ambient Regulations," Los Alamos National Laboratory document LA-UR-82-3061 (October 1982), 16 pp.	Presents a method for reducing complex meteorological relationships between sources and receptors to simple functions that can be used in mathematical models of air pollution regulation.
7. A. Ford, M. Baughman, H. Cooper, and D. Kamat, "Financial Impacts of Proposed New Source Performance Standards on the Electric Utility Industry," *Energy Systems & Policy* 3, No. 2 (1979), 31 pp.	Simulates the financial impacts of additional air pollution control costs with the Baughman-Joskow regionalized electric utility model. Concludes that the financial health of the industry is much more dependent on state regulatory commission policies than on the magnitude of additional control costs.
8. D. Nochumson, "Regional Air Quality in the Four Corners Study Region," *Air Pollution Control Association Journal* (July 1983), 8 pp.	Evaluates potential regional air quality impacts through the year 1995 for alternative energy scenarios under current and alternative regulatory policies. The alternative policies include emission fees, technology standards, emission ceilings, and prevention of significant deterioration.
9. D. Nochumson, "An Evaluation of Regional Haze Visibility Impacts," *The Environmental Professional* 4 (1982), 12 pp.	Evaluates regional haze visibility impacts as related to future energy development. Estimates the visibility impacts for Air Quality Control Regions located in the continental US and summarizes the findings by federal region. Estimates visibility impacts for the scenario years of 1980 and 2000 and compares them with visibility in 1975.

TABLE III: ENVIRONMENTAL CONSTRAINTS TO ELECTRICITY GENERATION (CONT)

DOCUMENT	DESCRIPTION
10. M. Williams, L. Chan, and R. Lewis, "Validation and Sensitivity of a Simulated Photography Technique for Visibility Modeling," *Atmospheric Environment* 15 (October/November 1981), 20 pp.	The Los Alamos visibility model is capable of producing simulated "before" and "after" pictures that illustrate visual effects of smoke plumes. The field study took place during August of 1979 near coal-fired power plants in Northwestern New Mexico and Northern Arizona. Telephotometer, NO_x plume measurements, and aerosol size distribution measurements were made in the plumes of three coal-fired power plants. Photographs were taken of the plumes and compared with simulated photographs from the model.
11. D. Nochumson, "A Screening Methodology for Calculating Worst Case Concentrations Downwind From a Large Isolated Air Pollutant Emission Source," Los Alamos National Laboratory report LA-8871-MS (September 1981), 24 pp.	Presents a screening methodology to indicate whether a proposed source to be sited in a flat or a high-terrain location has the potential to violate ambient air quality standards. The methodology is applied to a case study that examines the siting of generic coal-fired power plants in the West and the constraints imposed by terrain and sulfur dioxide air quality standards.
12. M. Williams, C. Mangeng, S. Barr, and R. Lewis, "Air Quality in the Four Corners Study Region, Vol. I: Local Analysis," Los Alamos National Laboratory document LA-UR-81-1145 (March 1981), 218 pp.	Examines prevention of significant deterioration (PSD) increment violations for Class I, II, and III areas and plume blight with respect to the 1977 Amendments of the Clean Air Act.
13. D. Nochumson, "Air Quality in the Four Corners Study Region, Volume II: Regional Analysis," Los Alamos National Laboratory document LA-UR-81-1145 (March 1981), 54 pp.	Examines regional pollutant loadings, ambient concentrations, and visibility impairment with respect to the 1977 Amendments of the Clean Air Act.
14. M. Williams, P. Cooper, and M. Wecksung, "Description of Warner Valley-Zion National Park Plume Blight Simulations," prepared for the National Park Service, Denver Service Center, Colorado (May 1980), 8 pp.	Describes the application of the Los Alamos visibility model to the proposed Warner Valley power plant near Zion National Park. Simulated photographs corresponding to three vantage points and single and double unit operations were prepared. From one vantage point, the plume would not be perceptible. From the others, a perceptible plume would be expected with adverse atmospheric conditions.
15. M. Williams, E. Treiman, and M. Wecksung, "Plume Blight Visibility Modeling with a Simulated Photograph Technique," *Air Pollution Control Association Journal* 30 (February 1980), 4 pp.	Describes a model that produces simulated "before" and "after" pictures of visible plumes from hypothetical sources. The chemistry, dispersion, and optical components of the model are described along with the model's application to hypothetical coal-fired power plants.

TABLE III: ENVIRONMENTAL CONSTRAINTS TO ELECTRICITY GENERATION (CONT)

DOCUMENT	DESCRIPTION
16. S. Ben-David, G. Bonem, A. Kneese, W. Schultze, D. Willet, and M. Williams, "Benefit-Cost Framework for Analysis of Trace Element Emissions From Coal-Fired Power Plants," Department of Energy report DOE/EV/10142-1 (November 1979), 234 pp.	Describes the qualities of various trace elements produced by coal-fired power plants in the Southwest. Partitioning of trace elements between solid water and air emissions is estimated. Finally, atmospheric dispersion and deposition of trace elements are estimated and possible effects delineated.
17. L. Wangen and M. Williams, "Elemental Deposition Downwind of a Coal-Fired Power Plant," *Water, Air and Soil Pollution* **10** (1978), 12 pp.	Calculates dry deposition of fly ash emitted by a coal-fired power plant using a surface depletion Gaussian plume model. Soil samples collected downwind of this power plant have been chemically analyzed for selected trace elements to determine concentration versus distance trends. Gaussian plume deposition calculations predict very little increase of trace element concentrations in soils, except for those elements highly concentrated in fly ash emissions.
18. A. Kneese and M. Williams, "Air Quality Issues and Approaches in the Southwest," *National Resources Journal* **19** (July 1979), 49 pp.	Describes current air quality regulatory approaches and their implications for air quality and siting of power plants in the Southwest. Also describes alternatives to air quality regulations.
19. M. Williams, S. Fry, W. Harrington, and G. Weatherford, "Siting Coal-Fired Power Plants in the Rocky Mountain Region: Legal, Technological, and Physical Variables Related to Air Quality," prepared by the John Muir Institute for the Los Alamos National Laboratory (1978), 131 pp.	Identifies many of the major variables related to air quality that must be considered in siting coal-fired plants, and describes the relative influence of those variables in case study simulations involving the Rocky Mountain Region. Part One sets out the air quality legal variables; Part Two reviews the technological variables related to emission control; and Part Three contains an ambient air analysis with case study simulations.
20. J. Devaney, "Physics-Related Problems of Coal-Fired Power Plant Pollution," *The Physics Teacher* (September 1978), 8 pp.	Assesses radioactivity of air pollution emissions from coal-fired power plants and concludes that radioactive emissions are greater from this source than from nuclear plants.
21. J. Devaney et al., "Environmental Effects and Potential Hazards of Laser Fusion Electric Generating Stations," Los Alamos Scientific Laboratory document LA-UR-77-2275 (1977), 4 pp.	Preliminary assessment of conceptual laser fusion power plant hazards and environmental impacts suggests that a modest chemical hazard under abnormal conditions will be the principal concern.

TABLE IV: THE DEMAND FOR ELECTRICITY

DOCUMENT	DESCRIPTION
1. A. Bopp and R. Pendley, "A Note on Estimating Elasticities Using Lagged Endogenous Variables," *Intermountain Economic Review* (Fall 1978), 7 pp.	Demonstrates the limitations of distributed lags of consumption variables often used to obtain short-and long-term elasticity estimates.
2. A. Bopp and R. Pendley, "Pooling Cross-Sectional and Time Series Data in the Presence of Autoregressive Disturbances," *New England Journal of Business & Economics* (Fall 1978), 8 pp.	Demonstrates that commonly used pooling techniques yield biased results in the presence of autoregressive disturbances; suggests appropriate countermeasures.
3. R. Sutherland, "Instability of Electric Demand Functions in the Post Oil Embargo Period," *Energy Economics* (October 1983), 6 pp.	Examines the temporal stability of electric demand functions with distributed lags over the 1961-1980 period. Demand functions are estimated for the residential, commercial, and industrial sectors and are tested for stability in the pre-and post-oil-embargo period.
4. R. Sutherland, "Distributed Lags and the Demand for Electricity," *The Energy Journal* 4, Special Electricity Issue (December 1983), 10 pp.	Uses the polynomial lag procedure to estimate the distributed lag effect of price, income, and natural gas price on electricity consumption. Results for the residential, commercial, and industrial sector are presented, which do not support the commonly held view that effects decline geometrically over time.
5. R. Sutherland, "The Demand for Electricity: Stock Versus Flow Adjustment Models," Los Alamos National Laboratory document LA-UR-82-3482 (1982), 12 pp.	Shows a stock adjustment and flow adjustment electric demand model that produces the same final-form equation except for differences in the long-run elasticities. Two-stage least squares estimates are obtained for three sectors. The estimated elasticities depend on whether a stock adjustment or flow adjustment model is being assumed.
6. R. Sutherland and R. Drake, "The Effect of Industrial Structure on the Demand for Electricity: Myth or Reality," presented at Electric Power Research Institute Workshop, Palo Alto, California, October 25, 1983, Los Alamos National Laboratory document LA-UR-83-2808 (September 1983), 8 pp.	Explains trends in electricity consumption in terms of the price of electricity, the GNP, and the price of substitutes.

TABLE V: SMALL VERSUS LARGE POWER PLANTS

DOCUMENT	DESCRIPTION
1. G. Friedlander (Editor), "Reconsidering Smaller Power Plants," *Electrical World* (July 1, 1979), 3 pp.	Briefly summarizes the Los Alamos study of small versus large coal-fired power plants in the Rocky Mountain West.
2. A. Ford and T. Flaim, "An Economic and Environmental Analysis of Large and Small Electric Power Stations in the Rocky Mountain West," Los Alamos Scientific Laboratory report LA-8033-MS (October 1979), 294 pp.	Presents a full accounting of the assumptions, analyses, and findings of the Los Alamos study. Roughly half of the report is devoted to the environmental analyses.
3. A. Ford et al., "A New Look at Small Power Plants," (five articles) *Energy Systems & Policy* 4, No. 1-2 (1980).	A collection of five articles is devoted to the results of the Los Alamos study with emphasis on the economic analyses.
4. A. Ford et al., "Is Smaller Better?" *Environment* (March, April, May, June 1980).	A collection of four articles is devoted to the results of the Los Alamos study with emphasis on the environmental analyses.
5. D. Abbey et al., "Nuclear Electric Capacity Expansion in Mexico: System Effects of Reactor Size and Cost," Los Alamos National Laboratory report LA-9681-MS (April 1983), 25 pp.	Evaluates the cost of differently sized nuclear reactors installed on Mexico's interconnected electric grid. Evidence of scale economies in the 600- to 1300-MW range is not compelling due to uncertainty in cost-scaling and capacity factors.

TABLE VI: REGULATORY REFORM, NUCLEAR POWER COSTS, RELIABILITY, AND LASER FUSION

DOCUMENT	DESCRIPTION
REGULATORY REFORM	
1. R. Drake et al., "Quantitative Analysis of Nuclear Power Plant Licensing Reform," Los Alamos National Laboratory report LA-9519-MS (September 1982), 67 pp.	Describes the use of the Los Alamos PERT chart Monte Carlo model to quantify the savings in time and money associated with the Energy Department's proposed changes in the licensing and construction of commercial nuclear power plants.
2. R. Drake, "Full Implementation of DOE's Licensing Reforms Could Cut $430-Million," *Nucleonics Week*, (October 14, 1982), 1 p.	Summarizes the findings of the Los Alamos study and the debate in Washington over alternative reforms in the nuclear licensing process.
NUCLEAR POWER COSTS AND BENEFITS	
1. R. Sutherland, "The Economic Benefits of Nuclear Power," Los Alamos National Laboratory document LA-UR-83-1653 (November 1983), 24 pp.	Estimates the historical and projected benefits of nuclear power as the cost differential between nuclear power and an alternative baseload generating source times the quantity of electricity generated.
2. R. Hardie, "POPCYCLE: A Computer Code for Calculating Nuclear and Fossil Plant Levelized Life-Cycle Power Costs," Los Alamos National Laboratory report LA-9127 (February 1982), 35 pp.	Includes derivations of the equations, a list of required input, and a sample case.
3. R. Hardie, "BICYCLE II: A Computer Code for Calculating Levelized Life-Cycle Costs," Los Alamos Scientific Laboratory report LA-8909 (August 1980), 34 pp.	Includes derivations of the equations, a list of required input, and a sample case.
4. R. Hardie and G. Thayer, "Analysis of Nuclear Economics," Los Alamos National Laboratory report LA-8899-MS (June 1981), 31 pp.	A briefing booklet describing several economic issues of nuclear power.
5. R. Drake, A. Youngblood, and D. Williams, "Nuclear Rate Increase Study," Los Alamos National Laboratory document (to be published).	Estimates the effect of new nuclear plants on electricity prices for 51 plants currently under construction.
6. R. Sutherland, "A Portfolio Analysis Model of the Demand for Nuclear Power Plants," Los Alamos National Laboratory document LA-UR-83-2868 (June 1983), 19 pp.	Uses a portfolio selection model to explain the coal versus nuclear composition of generating capacity. High-risk nuclear plants can reduce total risk compared with generating portfolios that include only coal plants.

TABLE VI: REGULATORY REFORM, NUCLEAR POWER COSTS, RELIABILITY, AND LASER FUSION (CONT)

DOCUMENT	DESCRIPTION
NUCLEAR POWER RELIABILITY	
1. M. Bryson, "Reliability Problems in Power Generation Systems," Los Alamos National Laboratory document LA-UR-80-2354 (October 1980), 20 pp.	Surveys reliability problem areas and the literature covering them in 10 areas related to power system reliability.
2. H. Martz and R. Beckman, "Nuclear Reactor Component Populations, Reliability Data Bases, and Their Relationship to Failure Rate Estimation and Uncertainty Analysis," Los Alamos National Laboratory report LA-9115-MS (December 1981), 24 pp.	Discusses the extent to which statistical methods can be used to obtain component failure rate estimates, and is illustrated by several simple examples.
3. H. Martz and M. Bryson, "On Combining Data for Estimating the Frequency of Low Probability Events," *Nuclear Science and Engineering* (February 1983), 14 pp.	Develops procedures for combining five different types of data to estimate component failure rates, and applies those procedures to the failure rate problem for sodium valves in nuclear power plants.
4. H. Martz and J. Johnson, "Assessing Compatibility With Reactor Safety Goals Using Uncertain Risk Analysis Results, With Application to Case Melt," Los Alamos National Laboratory document LA-UR-83-1050 (May 1983), 28 pp.	Uses Bayesian theory to determine, for a given probability risk assessment, the probability that a given reactor meets safety goal specifications.
5. H. Martz et al., "A Comparison of Methods for Uncertainty Analysis of Nuclear Power Plant Safety System Fault Tree Models," Los Alamos National Laboratory report LA-9729-MS (August 1983), 178 pp.	Compares five methods for analyzing uncertainty using computer simulation, and applies these methods to large fault trees from the Arkansas Nuclear One nuclear power plant.
LASER FUSION	
1. E. Leonard and C. Kolstad, "An Optimization Model for Electricity Production from a Laser Fusion Power Plant," Los Alamos Scientific Laboratory document LA-UR-79-1257 (1979), 1 p. (Abstract).	Presents an engineering-economic model of a laser fusion power plant. The model is used in a nonlinear optimization framework to minimize production costs of electricity.
2. J. Pendergrass et al., "Capital Cost Data Base for Laser Fusion Power Plants," Los Alamos Scientific Laboratory document LA-UR-79-1681 (1979), 4 pp.	Develops a data base for laser fusion power plants and addresses the special requirements of trade-off and parameter studies and the unique characteristics of laser fusion.

TABLE VI: REGULATORY REFORM, NUCLEAR POWER COSTS, RELIABILITY, AND LASER FUSION (CONT)

DOCUMENT	DESCRIPTION
3. J. Devaney et al., "Preliminary Assessment of Potential Accidents of Laser Fusion Electric Generating Stations," Los Alamos Scientific Laboratory document LA-UR-77-262 (1977), 3 pp.	Presents estimates of the probable consequences of accidents or sabotage of a laser fusion generating station. In general the chemical hazard of large scale lithium fires is the dominant hazard. Because of the extreme difficulty of disruptive access to significant radioactivities, sabotage or natural disaster is unlikely to release activities that are significantly worse than the instigative event itself.
4. E. Leonard and L. Booth, "Electric Power Generation Using Heavy Ion Fusion," Los Alamos Scientific Laboratory document LA-UR-79-3503 (1979), 6 pp.	Investigates the use of heavy ion fusion for electric power generation and concludes that this source is promising although difficult problems remain. Special emphasis is placed on the gain curve calculations because the cost of power is sensitive to this parameter.
5. L. Booth and R. Krakowski, "Fusion Electric Generating Station Systems," Los Alamos Scientific Laboratory document LA-UR-76-2691 (1976), 2 pp.	Identifies problems associated with transferring fusion energy to a working fluid and conversion to electricity. The systems considered are (1) plasma-confinement-system power supply, (2) the lithium/tritium processing and fuel cycle system, and (3) the heat transfer and energy conversion system.

DOE F 1325.8

United States Government | Department of Energy
memorandum | Albuquerque Operations Office

DATE **MAR 20 1984** | Attachment D

REPLY TO ATTN OF ETD:RLH(1014)

SUBJECT Guidance for Final Inputs to Multi-Megawatt Phase I Study

TO Those on Attached List

The purpose of this letter is to provide guidance for your final inputs to the Multi-Megawatt Phase I Study and to provide information on the final technical exchange meeting on April 16 and 17, 1984. This meeting will be held in Conference Room #3, Building 413, Kirtland AFB West beginning at 8:00 a.m. on April 16. The agenda for this meeting is included as Attachment 1.

Presentations should include a review of concepts considered against the military missions. Emphasis in your presentations should be placed on technology development needs associated with those concepts as well as the requisite development plans to meet those needs. Please allow adequate time for questions and discussions on your presentations. The Project Office requests five hard copies of your presentations in addition to your final report.

Security of this material must be emphasized. It is not the responsibility of the Project Office to decide the classification of your reports or presentation. That is your responsibility. Guidance on classification is again provided in Attachment 2. It is your responsibility to protect documents during your travel. Consult with your local security office for wrapping requirements and needed courier letters. There will be AFWL personnel available on Sunday, April 15, to provide access to safes if you notify Ms. Andrada at 505-844-0251 of your arrival time prior to 4:30 p.m. on April 13. Last minute changes can be accommodated by calling Lt. Col. Lee at home at 505-821-8785.

The meeting will be classified SECRET. A list of all attendees is required at AFWL prior to April 10, 1934. Please insure all attendees have clearance on file at AFWL with NTYN. If you have questions on your clearance status, please call Ms. Andrada ASAP at 505-844-0251.

The final report on the Phase I Study and the single technology development plan is due at DARPA on May 1, 1984. Because of this stringent deadline, the Project Office needs the support of at least four laboratories to help integrate and coordinate the initial planning and technology development efforts. The laboratories being requested to participate in this initial planning are NASA Lewis Research Center, Oak Ridge National Laboratory, Sandia National Laboratories and Los Alamos National Laboratory. DOE will work with the three DOE laboratories to coordinate their assistance in this planning process. The assigned areas of responsibility for each of these laboratories are shown in Attachment 3. Within their assigned areas the laboratories are to:

1. Review inputs by all participating laboratories and develop technology plans for project office approval.

2. As directed by the project office, provide technical guidance in the technology development planning process.

It should be emphasized that the selection of a laboratory to provide technical support in a specific area of responsibility does not suggest that work in that area will be performed by that laboratory. It is the Project Office intention to ensure that technical tasks are performed by those best qualified to do the work, whether they are government laboratories or organizations from the private sector.

To aid the Project Office and the support laboratories in the integration of the various laboratory inputs into a single technology development plan by May 1, Attachment 4 will be the outline for your written reports. Please submit written descriptions of your systems concepts in the format indicated in Attachment 5, and your enabling technologies as in Attachment 6. The enabling technologies are to be categorized according to the development areas listed in Attachment 3. These descriptions of system concepts and enabling technologies should be limited to ten and two pages, respectively. The enabling technologies should address those areas in which order of magnitude improvements can be expected from a reasonably aggressive technical development program.

Please submit your inputs (Attachments 4, 5 and 6) to Ron Holton, USDOE/AL, P.O. Box 5400, Albuquerque, NM 87115, with copies to Lt. Col. Lee, AFWL and the responsible laboratory by April 9, 1984. (See Attachment 9) As time permits, information received as late as April 17 will be incorporated into technology development plans. Attachments 7 and 8 illustrate the consolidated technology requirements and schedule that will be developed from your detailed technology inputs. This will help prioritize funding allocations in the first years of this project. Again, because of the extremely short time to complete this effort, the enormity of the task and the difficult decisions that must be made, the importance of your individual presentations cannot be overemphasized.

If you have further questions, please contact Lt. Col. Lee at 505-844-0251 or Ron Holton, DOE/AL FTS 846-5208.

Dennis L. Krenz
Director, Energy
Technologies Division

9 Attachments

Attachment 1

Multi-Megawatt Presentations
April 16-17, 1984

Kirtland AFB
Bldg. 413 Room #3

AGENDA

Monday, April 16		Tuesday, April 17	
0800	Introduction	0800	Preliminaries
0815	NASA Lewis Research Center	0815	LANL/SNL
1015	Break	1045	Break
1030	LLL	1100	ORNL
1200	Lunch	1215	Lunch
1300	ANL	1315	ORNL (cont.)
1515	Break	1415	BNL
1530	APL	1515	Break
1630	AFWL	1530	BNL (cont.)
1730	Adjourn	1645	Discussion
		1715	Adjourn

Attachment 2

Classification Guidance

a. All SP-100 MMW planning activities and documentation will be at the SECRET level. No unclassified meetings or discussions on the scope; objectives, content funding or any other aspects of MMW at this time.

b. Detailed classification guidance to be provided. Technology issues that are sufficiently far removed from systems or mission issues may be addressed at an unclassified level. When you doubt, please conduct your business on a classified basis.

c. All documentation must be stamped SECRET and marked as follows:

Classified by: SDI (Strategic Defense Initiative)
Declassify on: OADR

Attachment 3

Laboratory Responsibilities by development area

LANL

- Bi-Modal and Burst Reactor Concepts
- Nuclear Fuels Development
- Radiators
- Primary Heat Transport

ORNL

- Steady State Reactor Concepts
- Shielding
- Materials (non-fuels)
- Energy Storage for burst power and load following

SNL

- Surety
- Instrumentation, Communication and Control
- Power Conditioning
- Spacecraft Structures

SNL/NASA LeRC

- Energy Conversion

NASA LeRC

- Aerospace Technology
- Trade-off and Evaluation Studies
- Non-Nuclear Options (Chemical)

Attachment 4

Multi-Megawatt Technology Development Report Outline

Executive Summary

A. Introduction
(Background, objectives and scope of study, etc.)

B. Missions Considered
(Development of power systems requirements to serve as the basis for this study)

C. Systems Concepts
(Descriptions of systems to meet the requirements developed in B. This section is not limited to but should include all information requested in Attachment 5. You may incorporate or attach as an appendix copies of Attachment 5 for each system concept.)

D. Enabling Technologies
(Identification of those technology areas requiring some advancement to meet performance goals for the systems concepts described in C. This section is not limited to but should include all information requested in Attachment 6. You may incorporate or attach as an appendix copies of Attachment 6 for each enabling technology.)

E. Technology Development Plan
Brief description of a program to develop those technologies identified in D; include schedules and costs.)

F. Appendices as Appropriate

Attachment 5

System Description

Provide a five to ten page description of the complete system to meet a mission application. (You may reference supplemental information, but the description should stand by itself.)

Areas to be included:

- Mission it meets
- Description of system
- Description of subsystem functions
- Major system parameters, e.g. mass, volume
- Enabling technologies
- Areas of major technical risk
- Potential for meeting expanded requirements

Attachment 6

SUBMITTING ORGANIZATION:

DEVELOPMENT AREA:

ENABLING TECHNOLOGY:

OBJECTIVES:

PURPOSE:

POTENTIAL APPLICATION:

APPROACH:

SCHEDULE:

COSTS:

Attachment 6
(Instructions)

SUBMITTING ORGANIZATION:

DEVELOPMENT AREA: (selected from Attachment 3)

ENABLING TECHNOLOGY: (descriptive title)

OBJECTIVES: (A description of the advances needed in this enabling technology, e.g., nuclear fuel operating 10 years at 1,800 k, 10% burnup)

PURPOSE: (A description of the system or subsystem gains from the successful development of the technology. A description of the present capability might be appropriate.)

POTENTIAL APPLICATION: (A description tracing the technology back through subsystems and systems concepts to mission requirements.)

APPROACH: (required activities, major milestones and performing organizations)

SCHEDULE: (activities and milestones vs. time)

COSTS: (in general, estimates of first year and balance of program costs)

Attachment 7

Multi-Megawatt Space Power
Technology Development (Illustration)

DEVELOPMENT AREA	CONCEPT A	CONCEPT C	CONCEPT N
Energy Source	Cadidate Device	Candidate Device	Candidate Device
	Enabling Technologies	Enabling Technologies	Enabling Technologies
Energy Conversion			
Thermal Management			
Power Management		E.G. Sodium Sulfur Cell	E.G. Sodium Sulfur Cell
		E.G. high Energy Density Storage Batteries	E.G. High Energy Density Storage Batteries
Inst., Comm., & Control			
Surety			

NOTE: This matrix maps into the technology development plans shown on the following page and permits the reader to trace the proposed technology to a specific concept.

Attachment 8

Technology Development Plan (Illustration)

	FY85	FY86	FY87	FY88 --- FY91	COST $M
Enabling Technology					
Nuclear Fuel Materials					
Structural Materials					
High Energy Density Storage	Batteries		Cell Config.	Electrolyte & Electrode Development Packaging Tech.	1.0
High Temp. & Rad. Hardened Electronics					
High Temp. Turbine-Generator					
Surety					

Attachment 9

Laboratory Classified Mailing Addresses

Oak Ridge National Laboratory

Attn: Classified Central File
Oak Ridge National Laboratory
P.O. Box X
Oak Ridge, TN 37831

Inside Envelope Addressee: Dr. David Bartine

Sandia National Laboratories Albuquerque

Attn: Mail Services
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185

Inside Envelope Addressee: Lou Cropp, Org. 6433

Los Alamos National Laboratory

Los Alamos National Laboratory
Mail Station 5000
P.O. Box 1633
Los Alamos, NM 87545

Inside Envelope Addressee: Dr. T. J. Trapp

Addressees Per Memo Dated MAR 20 1984 -3-

E. Wahlquist, NE-54, DOE HQ
J. Jicha, DP-123, DOE HQ
General Hardin, OOM, AL
Col. R. Redd, AFSTC
Lt. Col. J. Lee, AFWL/NTYN (2 copies)
J. Reams, AFWAL/POO
L. Beale, AFRPL
J. Boudreau, ES-NP/F671, LANL
T. Trapp, E561, LANL
D. Bartine, ORNL
A. Snyder, Org. 6400, SNLA
L. Cropp, Org. 6448, SNLA
R. Lewis, ANL
J. Powell, BNL
C. Walton, LLNL
R. Sovie, NASA LeRC

Attachment E

MEMORANDUM OF AGREEMENT
BETWEEN THE
DEFENSE ADVANCED RESEARCH PROJECTS AGENC
OFFICE OF AERONAUTICS AND SPACE TECHNOLOG
AND THE
OFFICE OF NUCLEAR ENERGY (DoE)
CONCERNING THE DEVELOPMENT OF
SPACE NUCLEAR REACTOR POWER SYSTEM TECHNOLOGY
(SP-100 PROGRAM)

1. Purpose of this Agreement.

This memorandum of agreement establishes procedures whereby the Defense Advanced Research Projects Agency, the Office of Aeronautics and Space Technology, and the Office of Nuclear Energy will jointly develop technology necessary for space nuclear reactor power systems for military and civil applications. This agreement establishes the SP-100 Program.

2. Objectives and Scope of the Joint SP-100 Program.

In scope the SP-100 Program has the DoD, DoE, and NASA charter for all space nuclear reactor power systems technology development.

Specific SP-100 Program objectives are:

a. Insure safety is fully considered.

b. Establish performance limits and military and civil utility for space nuclear power in 100 kilowatt and multimegawatt classes.

c. Assess and advance technology for a 100 kilowatt class space nuclear power system in support of military and civil missions.

d. If a reasonable need for multimegawatt space nuclear power exists, embark on long range technology development program.

e. Insure orderly and effective transition from technology assessment and advancement to engineering development and production for users as warranted.

3. Management Structure.

During the technology assessment and advancement phase, an SP-100 Program Office, headed by a director and two deputies, will report directly to the Director of DARPA with programmatic direction from a tri-agency Steering Committee. The Program Office will be located at DARPA in Washington, D.C. A project manager and project office at the Jet Propulsion Laboratory will report to the program director and will, through appropriate principal deputies, manage all SP-100 technical work. All SP-100 technical direction and funding will pass directly through the program director and project manager. The funding channels peculiar to the individual parties to this agreement may be used, but all funds will be expended in accordance with specific written direction from the project manager endorsed by the program director.

Upon selecting a specific system for an engineering feasibility demonstration, the management will revert to a more traditional line structure with separate activities and clearly defined interfaces. The Department of Energy shall be completely responsible for developing, at a minimum, the nuclear subsystem in any follow-on development effort.

The Steering Committee will be chaired by DoE and composed of a representative from each agency. The following or their designees comprise the Steering Committee:

DoD	Director, DARPA
DoE	Assistant Secretary for Nuclear Energy
NASA	Associate Administrator, OAST

The Director, DARPA will seek to establish a senior level Military Service Review Group to work closely with the Steering Committee.

The SP-100 Program Director will be provided by DARPA; the program director, the program manager and their deputies, will be appointed with the concurrence of the Steering Committee.

A detailed SP-100 Management Plan amplifying this agreement will be promulgated early in the program.

4. Responsibilities.

a. The Steering Committee shall approve overall SP-100 objectives and plans, approve appointments of key personnel, review technical progress, and ensure proper support is provided to the program by their parent organizations.

b. The SP-100 Program Director shall be responsible to the Steering Committee for the execution of the program and will communicate directly with them on status, progress, and problems.

c. The project manager will be responsible to the program director for the detailed planning and execution of the SP-

100 technology development project. He has complete technical and budgetary authority subject to guidance from the program office.

d. A deputy project manager for nuclear technology from an appropriate national laboratory or contractor engaged in the nuclear technology work, and appointed by DoE, will report to the project manager. This deputy project manager will have complete authority, within the system framework, for nuclear techology, design, and engineering.

Detailed responsibilities of the program director, deputies, and the project manager will be delineated in the SP-100 Management Plan.

5. Funding Commitments.

Funding will be provided in the critical technology phase as follows:

Current Year $M

	FY82	FY83	FY84	FY85
DARPA	2.0	4.0	5.0	8.0
DoE	1.3	2.5	4.1	4.1
NASA	2.4 (+5dmy*)	2.9 (+10dmy)	3.9 (+10dmy)	3.9 (+10dmy)
Total	5.7	9.4	13.0	16.0

Funding shares for additional years of the technology assessment phase if any will be established at a program review midterm in this effort. It is the intention of the parties to treat the agreement as a contract which can be changed only by mutual agreement. Hence, subject to the approval of the Administration and Congress, funding shares will be decreased only by unanimous written consent of all parties.

6. Miscellaneous Provisions.

This agreement is effective on the date it is signed.

The agreement can be amended and modified at the written request of any one of the parties. The amendment or modification shall be negotiated and signed by the same authorities as the original agreement.

---

*dmy = direct man-year

This document does not constitute an authority for the transfer of funds. Each agency shall use established fiscal policies and procedures for disbursement of funds.

Defense Advanced Research Projects Agency (DoD)	Office of Aeronautics and Space Technology (NASA)	Office of Nuclear Energy (DoE)
Robert S. Cooper	Jack L Kerrebrock	Shelby T Brewer 2/11/83
Robert S. Cooper Director	Jack L. Kerrebrock Associate Administrator for Aeronautics & Space Technology	Shelby T. Brewer Assistant Secretary for Nuclear Energy

INCOMING

NASA

Facsimile Transmission

(Instructions on Reverse)

TRANSMITTING STATION NO	2 VOICE PHONE CONTACT NO.	3 MESSAGE NO.	4. TOTAL PAGES (Including lead)	5 DATE
		306	5	2/14/83

FROM (Name, organization and location)

Judith Ambrus
NASA Headquarters
Washington, DC 20546

7. OFFICE CODE RTS-6 755-3273

8. OFFICE PHONE NO 755-3273

TO (Include Office Code and telephone number.) (May also be used for remarks)

JPL/Jim Kelly 792-7956

Los Alamos National Labs/Jay Boudreau TelFAX No. 843 6937
Confirmation No. 843-5113 M.S. 671

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

MAR 21 1984

The Honorable Marilyn Lloyd, Chairman
Subcommittee on Energy Research
and Production
Committee on Science and Technology
United States House of Representatives
Washington, D.C. 20515

Dear Madame Chairman:

Thank you for your and the Subcommittee's continuing interest in our high-level waste regulatory program. Enclosed are our responses to the questions in your letter of February 24, 1984.

Sincerely,

William J. Dircks
Executive Director for Operations

Enclosures:
Responses to Questions in
ltr dated February 24, 1984

QUESTION 1: What is the NRC doing to maintain close cooperation with the Department of Energy in the early stages of the repository program? How many people does the NRC have following this issue?

ANSWER.

Although the differing missions of the two agencies preclude a collaborative relationship, NRC staff is working to maintain close communication with DOE in several areas of the repository program. We have begun to establish a framework of interagency agreements to govern our interactions, and in June, 1983, we concluded a procedural agreement setting forth guiding principles for NRC-DOE interaction during site investigation and site characterization (See 48 FR 38701, August 25, 1983). One of the important features of this agreement was a provision for on-site NRC representatives at each of the sites that DOE may be characterizing at the Basalt Waste Isolation Project at Hanford, Washington, the Nevada Test Site, and a salt site yet to be selected. We have also begun working with DOE on a subordinate implementing agreement directed at project-specific arrangements.

To establish an overall framework for interagency interactions in the implementation of the Nuclear Waste Policy Act, NRC staff is also drafting for DOE review an umbrella memorandum of understanding setting forth an Interagency Programmatic Agreement, which we hope to conclude by early summer. In the transportation area, we developed another procedural agreement in November, 1983, concerning the certification of spent fuel and high-level waste transportation packaging (See 48 FR 51875, November 14, 1983).

In addition to the use of on-site NRC representatives to keep headquarters staff informed and facilitate timely consultations, there are a number of mechanisms by which NRC and DOE are and will be maintaining close communication: 1.) Documented technical meetings and interactions; 2.) development of NRC regulatory guides and technical positions; 3.) NRC staff comments on DOE Site Characterization Plan and semi-annual reports on site characterization; and 4.) reviews of other DOE reports.

To develop the needed guidance and perform all the related activities necessary to maintain close liaison with DOE on potential licensing issues at each DOE project site at this stage, NRC has created a Repository Projects Branch with a staff of 19 professionals within the Division of Waste Management. Under the Division's new matrix form of management, however, additional resources from our Geotechnical and Engineering Branches are made available on an ongoing basis as needed for specific regulatory development projects.

QUESTION 2: One of the reasons for the Test and Evaluation Facility is to supplement the site characterization process for the development of licensing data. What does the NRC feel about this role for the Test and Evaluation Facility?

ANSWER:

The Commission has not taken a position on the need for a test and evaluation facility (TEF); under the Nuclear Waste Policy Act of 1982, the decision on whether to pursue a TEF, and of what type, is left to DOE's discretion. Under Sections 217 and 305 of the Act, DOE may construct and operate a TEF without obtaining an NRC license if the TEF is not collocated at a site DOE is characterizing for a repository.

We believe that DOE must make the decision on a TEF based on its costs and benefits and how effectively the TEF or some other means would satisfy the provisions of the Act, including the requirement under Section 217(c)(1)(F) that DOE's testing program include in situ tests under "abnormal repository conditions to establish safe design limits for disposal packages and to determine the effects of the gross release of radionuclides into surroundings, and the effects of various credible failure modes ...."

QUESTION 3: Does NRC intend to cooperate with the Department of Energy to meet the deadlines in the Waste Act wherever applicable to NRC?

ANSWER:

Yes. Bearing in mind the safety-related requirements of our statutory mission, NRC intends to provide timely guidance on licensing information needs, and to cooperate fully in the development of DOE's Mission Plan under Section 301 and Project Decision Schedule under Section (114(e) of the Act to assure the completion of high-quality work on a timely basis.

Question 4: Does the Nuclear Regulatory Commission have any criticism of DOE relative to the conduct of the West Valley Demonstration Project?

Answer.

The Nuclear Regulatory Commission (NRC) is maintaining close interaction with DOE on the West Valley Demonstration Project in accordance with the safety oversight role assigned to us by the West Valley Act. Based on our experience to date, including a number of site visits by NRC staff members, we have no criticism of DOE relative to its conduct of the Project. DOE and its site contractor, West Valley Nuclear Services (a subsidiary of Westinghouse), have moved swiftly to prepare for the solidification of the high-level wastes at West Valley. Safety has not been sacrificed. Decontamination of highly contaminated cells and adjacent areas in the reprocessing facility to provide for access and project use is proceeding effectively in a safe manner. DOE has kept us well informed on its planning and work activities, and it has been responsive to NRC comments. We were consulted prior to the decision on two key elements of the project, selection of the waste form and the solidification process, and the overall Project Plan called for by the Act is being prepared for NRC review.

Minority Question 2: It is the perception of some observers that the extent of clean up and decontamination at West Valley exceeds that amount necessary to implement and complete the waste solidification plan. Please comment.

Answer.

Although it is not the direct responsibility of the NRC to decide the extent of decontamination of the existing facility necessary for effective conduct of the solidification project, we do not perceive that the approach being taken by DOE involves excessive decontamination effort. The decontamination is proceeding under the principle of maintaining occupational radiation exposures as low as reasonably achievable (ALARA) not only during the clean-up activities, but for subsequent installation of equipment and services necessary for waste processing, solidification, and storage. Under present planning, it is our understanding that most of the existing cells and adjacent operating areas will be utilized during the project even though key components, such as the melter, melter feed tank, and canister handling system, would be contained in a new cell adjacent to and coupled with existing cells. Substantive use of the existing facility thus dictates extensive decontamination to assure the health and safety of workers and maintenance of effective contamination control during the project. Decontamination activities have included some areas outside the main structure for the same reasons. We believe that DOE is taking a reasoned and prudent approach to tailor the project to the existing site and minimize the overall time required for completion of the solidification project.

Minority Question 1: Please evaluate for the subcommitee the realism of the schedules provided in the Nuclear Waste Policy Act.

Answer.

We believe that the Commission will be able to reach a decision on repository construction authorization in the three to four years provided under the Act if DOE submits a complete and high-quality application containing sufficient and carefully-documented information on which to make licensing decisions. Whether DOE will be able to produce such an application within the 1987-88 timeframe provided under Section 114(a) of the Act will depend on the availability of resources, the complexity of the sites chosen for characterization, DOE's management strategy, and other factors beyond the Commission's control. For your further reference on NRC's view of DOE's planning assumptions for meeting the milestones set forth in the Act, our comments on the first volume of DOE's draft Mission Plan are attached.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

February 8, 1984

Mr. Michael J. Lawrence, Acting Director
Office of Civilian Radioactive
  Waste Management
U.S. Department of Energy
Washington, D.C. 20585

Dear Mr. Lawrence:

In response to Mr. Robert Morgan's request of December 20, 1983, I am pleased to provide comments on the working draft of the Department of Energy's (DOE) "Civilian Radioactive Waste Management Program Mission Plan, Volume I, Overview And Current Program Plans," dated December 20, 1983. We understand that Volume II, which is not yet available, will include more detailed information to address the eleven items specifically required by Section 301 of the Nuclear Waste Policy Act of 1982 (the Act), which would include a description of DOE's research, development, and technology demonstration program.

In my speech before the Civilian Radioactive Waste Management Information Meeting on December 13, 1983, I described the process by which the Commission will decide whether to authorize construction of a repository at a particular site. One of the distinctions I drew in that presentation was between the licensing staff, who make recommendations on whether and under what conditions a license should be issued; and the five Commissioners who have the ultimate authority to approve or disapprove DOE's license application for the waste repository. The enclosed comments on the working draft of Volume I of the Mission Plan are the views of the NRC licensing staff. The NRC's comments on the formal draft called for under Section 301(b) of the Act will receive Commission review.

I would like to highlight several observations that we've made on the draft Mission Plan's consideration of the licensing process and the need to develop sufficient data and analyses to support licensing findings in the adjudicatory evidentiary hearing process prescribed by 10 CFR Parts 2 and 60.

1. The draft Mission Plan adopts a development strategy which depends on receiving a limited work authorization to allow repository construction to start six months after the submission of the license application (pages 3-A-26, 27, 38 and 43). The Commission regulations do not provide for a limited work authorization for a geologic repository. In developing its regulations, the Commission explicitly considered the types of activities that would be permitted prior to the initial licensing decision and decided that construction should not be allowed to proceed without a comprehensive review of the license application.

2. On page 3-A-38, it is stated that the time for in-situ testing in salt and tuff to provide data for the selection of the first repository ranges from 8 to 27 months. It goes on to say, however, that some estimates from outside the Department indicate that 4 years or more will be needed for at-depth testing (3-A-42). While the plan recognizes that there may be other views and states that DOE will continue working with other groups on in-situ testing requirements, we believe that the estimates reported in the final Mission Plan should better reflect the uncertainty in the scale and duration of required testing and the need to provide sufficient information to support the licensing findings. There is particular uncertainty with respect to the testing that may be required to address thermal effects of waste emplacement on the host rock and groundwater. Over the past several years, the NRC staff has pointed out the need for DOE to address this issue as it has potential for large impacts on schedule. As you know, the USGS has estimated that underground testing to address such long term isolation issues may take 5 to 10 years to complete at the Hanford site. Resolution of this question is largely dependent on DOE's establishing site specific design performance requirements as discussed in item 5 below. DOE can reduce or eliminate uncertainties about testing needs by design measures such as limiting thermal loading. The Commission staff stands ready to consult with DOE on plans for design and to reduce uncertainties on testing needs. DOE should be aware that the quality of this testing and its documentation, we believe, is key to the selection process. It is in this area where we see the opportunity for issues to arise which will be particularly challenging for resolution.

3. On page 3-A-44 it is stated that because of the extensive, prelicensing interaction with the NRC, a 3-year licensing period has been assumed as specified in the Act. What's not mentioned is that the Commission's position before Congress on meeting this licensing schedule was conditioned on DOE submitting a high quality and complete license application for NRC review. The prelicensing interaction is intended to assist DOE in providing such an application by NRC informing DOE on a timely basis of areas the NRC believes need attention or a modified or increased examination by DOE.

The Commission believes that in order to assure that sufficient information is being gathered, a free and open exchange prior to the beginning of formal licensing is essential. As indicated by the completion of the DOE/NRC procedural agreement on repository programs, progress has been made in establishing effective and publicly accessible mechanisms for early identification and resolution of technical issues by DOE and NRC. The Mission Plan should recognize, however, that any of the issues being addressed in the prelicensing consultation process can be the subject of challenge before the hearing boards, even if the express concerns of the NRC staff had been accommodated. The plan should reflect the uncertainty about the duration of the hearing process that may result if the data presented in the license application is subject to legitimate dispute. In this connection, we also recommend that the repository program strategy include an active seeking by DOE of views of a wide cross-section of the technical community during the prelicensing consultation phase, to supplement the consultation and cooperation process prescribed by law.

4. The sequence for developing repository design information and supporting data does not appear to be consistent with what will be required to make findings under 10 CFR Part 60. Figure 3-A-5 shows that a Title I design will be completed prior to license application; however, Section 6(a) states that repository design will be completed after a license application is submitted and that "preliminary designs" for the repository and waste package will be initiated near the end of in-situ testing and provided with the license application. We recognize that greater levels of design detail will continue to be developed as the program progresses. However, detailed design information, along with data on engineered system components performance, will be required to demonstrate compliance with 10 CFR Part 60 performance objectives and requirements at the time of the submittal of a license application. "Preliminary information" on design will clearly not be sufficient to support licensing findings and a construction authorization by the Commission. The current ambiguity in the Plan on design development needs to be cleared up in the next draft. It is essential that the Mission Plan clearly reflects the requirements of 10 CFR Part 60.

5. Over the past year the NRC staff has informed DOE of the need to establish, as soon as possible, the intended performance requirements for repository system components on a site specific basis. 10 CFR Part 60 gives DOE flexibility, on a site-by-site basis, to propose tradeoffs among system components (natural and engineered). We believe that it is essential that decisions be made promptly by DOE for these intended component performance requirements. These decisions are essential to provide focus to the repository investigation programs. Without this focus, the programs may not provide an adequate or timely basis for DOE decisions or for NRC reviews. Also, NRC's ability to give timely guidance to DOE on licensing information needs may be hindered and in some cases made impossible. Section 5(b)(1) suggests that "top-level design basis, functional requirements, performance measures and performance criteria" are being developed. There is no specific statement, however, of when this will be done.

6. The discussions regarding construction of the underground portions of a collocated Test and Evaluation Facility (TEF) once site designation is effective (pages 3-A-25) appear inconsistent with the NWPA. In our opinion, the legislative history of the TEF provisions of the Act supports the conclusion that no construction, surface or subsurface, can

begin until after the Commission has authorized repository construction at the site.

7. As a final observation, the draft Mission Plan does not address a quality assurance program for either DOE's internal needs or the requirements in support of the adjudicatory hearings at the time of license application or waste emplacement. NRC regulations (10 CFR Part 60) require that data obtained/developed in support of the license application must be collected under a formal quality assurance program. DOE is expected to have a formal, documented QA program that can establish the accuracy, authenticity, and replicability of DOE's measurement data and related studies and its performance assessment models and computer codes. As noted in comment 2 above, we consider the demonstrable quality of DOE's program to be a key to its success.

Further comments on several of these points and additional observations on this working draft are enclosed.

Overall, I believe the National Waste Program would benefit greatly from the establishment of a schedule that better reflects the Commission's licensing process, and the time required to gain public acceptance of critical decisions which experience to date has shown to require more time than any of us have estimated.

As you are aware, the Commission has defined a procedure for considering whether to grant or withhold concurrence in the repository siting guidelines. As you probably recall from the January 11, 1984, public meeting on the guidelines, Chairman Palladino stated that their schedule was to have a preliminary Commission decision available by the end of February and a final Commission decision by the end of April. Since that time there have been requests by the states for more time to comment on the Commission's preliminary decision. At the meeting it was also stated by some Commissioners that changes would have to be made before the Commission could concur. Since we will be seeing the formal draft Mission Plan by early April for our review, I suggest that the schedules in that draft reflect these schedules for guideline concurrence and the narrative clearly describe any impacts to your program that result from both the change to your assumption on when concurrence would be made, and the potential need to revise the guidelines before Commission concurrence.

We appreciate the opportunity to provide these staff comments on your working draft. Since this Mission Plan and the Project Decision Schedule are very important to NRC as well as DOE planning, we urge continuing staff interaction to ensure timely preparation of these plans and schedules.

Sincerely,

John G. Davis, Director
Office of Nuclear Material
Safety and Safeguards

Enclosure: As Stated

NRC COMMENTS

ON THE

CIVILIAN RADIOACTIVE WASTE MANAGEMENT PROGRAM
MISSION PLAN

VOLUME I

OVERVIEW AND CURRENT PROGRAM PLAN

DECEMBER 20, 1983

406.1.6/GG/84/1/23/0

Comment #1 DOE interprets Section 114(f) of the NWPA as not requiring that three sites be designated as suitable for development as a high-level waste repository.

The statement that at least one site will have been shown to be suitable for development as a repository at the conclusion of site characterization (page 2-9) may be in conflict with the need for the Secretary to make a preliminary determination that the three sites considered in DOE's Environmental Impact Statement are suitable for development as repositories consistent with the guidelines promulgated under Section 112(a). The NRC staff is of the view that the preliminary determination must be made at a point where there is adequate data available from site characterization so that the guidelines can be applied in a meaningful way. It would be appropriate for the final Mission Plan to include an explicit discussion of when the preliminary determination under Section 114(f) will be made and what data will be necessary to support this determination.

Furthermore, DOE should address the NEPA implications of proceeding with a site recommendation when one or more of the three candidate sites has been found unsuitable. Specifically, the Department should explain how it intends to satisfy its NEPA responsibilities on the consideration of alternative sites in this event. The DOE approach to this NEPA issue may affect the ability of the Commission to adopt the DOE EIS.

Comment #2 We disagree with the DOE interpretation of Section 305 of the NWPA and with the assumption in the Draft Mission Plan (page 2-12) that subsurface construction of a Test and Evaluation Facility (TEF) collocated at a repository site can begin before the Commission has authorized construction for a repository at that site.

The discussions regarding construction of the underground portions of a collocated Test and Evaluation Facility (TEF) once site designation is effective (pages 3-A-25) appear inconsistent with both the NWPA and with 10 CFR Part 60. In our opinion, the legislative history of the TEF provisions of the Act supports the conclusion that no construction, surface or subsurface can begin until after the Commission has authorized construction at this site. Also, since construction of the collocated TEF could affect the licenseability of the site, it would be imprudent to initiate construction prior to Commission authorization of construction. The Department should address the possibility that the Commission may find that a repository cannot be constructed at the site without undue risk to public health and safety, and to explain what impact such a finding might have upon the collection of the data which the TEF was designed to provide.

A further discussion on Section 305 of the NWPA and its legislative history is presented in Appendix 1.

Comment #3 The DOE schedules for repository development are based on NRC granting a Limited Work Authorization (LWA)

The plan adopts a development strategy which depends on receiving a limited work authorization to allow construction to start six months after the submission of the application for construction authorization (pages 3-A-26, 27, 38 and 43). The Commission regulations do not provide for a limited work authorization for a geologic repository. In developing its regulations, the Commission explicitly considered the types of activities that would be permitted prior to the initial licensing decision and decided that construction should not be allowed to proceed without Commission review. While DOE may be considering that it request the Commission to amend this provision, it should be aware that some Commissioners have previously stated that an LWA would be inappropriate for this first of a kind undertaking. Finally, it appears unlikely that the necessary actions could be completed in the six month period assumed by DOE.

A further discussion on this comment is provided in Appendix 2.

Comment #4 The leadtime cited in the Mission Plan for in-situ site characterization should better reflect the uncertainity in the duration of testing which may be required to support licensing findings.

On page 3-A-38, it is stated that the time for in-situ testing in salt and tuff to provide data for the selection of the first repository ranges from 8 to 27 months. It goes on to say, however, that some estimates from outside the Department indicated that 4 years or more will be needed for at-depth testing (3-A-42). While the plan recognizes that there may be other views and states that DOE will continue working with other groups on in-situ testing requirements, we believe that the estimates reported in the final Mission Plan should better reflect the uncertainty on the scale and duration of required testing and the need to provide sufficient information to support the licensing findings. There is particular uncertainty with respect to the testing required to address thermal effects of waste emplacement on the host rock and groundwater. Over the past several years, the NRC staff has pointed out the need for DOE to address this issue as it has potential for large impacts on schedule. As you know, the USGS has estimated that underground testing to address such long term isolation issues may take 5 to 10 years to complete. DOE should be aware that the quality of this testing and its documentation, we believe, is key to the selection process. It is in this area that we see the opportunity for issues to arise which will be particularly challenging for resolution.

These views have been discussed in NRC/DOE working meetings and workshops.

U.S Geological Survey, letter to Mr. R.L. Morgan, DOE from Doyle G. Fredrick, USGS, subject: USGS Comments on the Basalt Waste Isolation Project, (page 9) dated August 25, 1983.

Lawrence Berkely Laboratory, Experiments, Conceptual Design, Preliminary Cost Estimates and Schedules for an Underground Research Facility, (LBL-13190), G. Korbin et al, September, 1981.

Comment #5 The repository design process described in the Draft Mission Plan does not provide assurance that the required level of detail will be available to support each stage of the repository development and licensing process.

A. The sequence for developing repository design information and supporting data does not appear to be consistent with what will be required to make findings under 10 CFR Part 60. Figure 3-A-5 shows that a Title I design will be completed prior to license application; however, Section 6(a) [beginning on page 3-A-24] states that repository design will be completed after a license application is submitted and that "preliminary designs" for the repository and waste package will be initiated near the end of in-situ testing and provided with the license application. We recognize that greater levels of design detail will continue to be developed as the program progresses. However, detailed design information, along with data on engineered system components performance, will be required to demonstrate compliance with 10 CFR Part 60 performance objectives and requirements at the time of the submittal of a license application. "Preliminary information" on design will clearly not be sufficient to support licensing findings and a construction authorization by the Commission. The current ambiguity in the Plan on design development needs to be cleared up in the next draft. It is essential that the Mission Plan clearly reflects the requirements of 10 CFR Part 60.

It is important that the Mission Plan clearly reflects the need to make all the findings specified in 10 CFR Part 60.31 including those related to both siting and design because the NRC staff has encountered a number of instances where DOE staff and contractors have indicated a belief that only general information on design and engineered components will be necessary for construction authorization. Failure to recognize and plan for what is required will almost certainly result in delays later in the program. These could conceivably be serious, as the lead times for completion of designs and some of the supporting testing can be quite long.

B. The requirements of NWPA (Section 113(b)(1)(C)) and 10 CFR Part 60 to complete a conceptual design and to provide site characterization plans is not clearly stated in the Mission Plan. It appears from the discussion in Section 6(a) [beginning on Page 3-A-24] that this will be developed during the site characterization rather than before it as necessary to provide a basis upon which to develop data gathering plans.

Comment #5 The repository design process described in the Draft Mission Plan does not provide assurance that the required level of detail will be available to support each stage of the repository development and licensing process.

A. The sequence for developing repository design information and supporting data does not appear to be consistent with what will be required to make findings under 10 CFR Part 60. Figure 3-A-5 shows that a Title I design will be completed prior to license application; however, Section 6(a) [beginning on page 3-A-24] states that repository design will be completed after a license application is submitted and that "preliminary designs" for the repository and waste package will be initiated near the end of in-situ testing and provided with the license application. We recognize that greater levels of design detail will continue to be developed as the program progresses. However, detailed design information, along with data on engineered system components performance, will be required to demonstrate compliance with 10 CFR Part 60 performance objectives and requirements at the time of the submittal of a license application. "Preliminary information" on design will clearly not be sufficient to support licensing findings and a construction authorization by the Commission. The current ambiguity in the Plan on design development needs to be cleared up in the next draft. It is essential that the Mission Plan clearly reflects the requirements of 10 CFR Part 60.

It is important that the Mission Plan clearly reflects the need to make all the findings specified in 10 CFR Part 60.31 including those related to both siting and design because the NRC staff has encountered a number of instances where DOE staff and contractors have indicated a belief that only general information on design and engineered components will be necessary for construction authorization. Failure to recognize and plan for what is required will almost certainly result in delays later in the program. These could conceivably be serious, as the lead times for completion of designs and some of the supporting testing can be quite long.

B. The requirements of NWPA (Section 113(b)(1)(C)) and 10 CFR Part 60 to complete a conceptual design and to provide site characterization plans is not clearly stated in the Mission Plan. It appears from the discussion in Section 6(a) [beginning on Page 3-A-24] that this will be developed during the site characterization rather than before it as necessary to provide a basis upon which to develop data gathering plans.

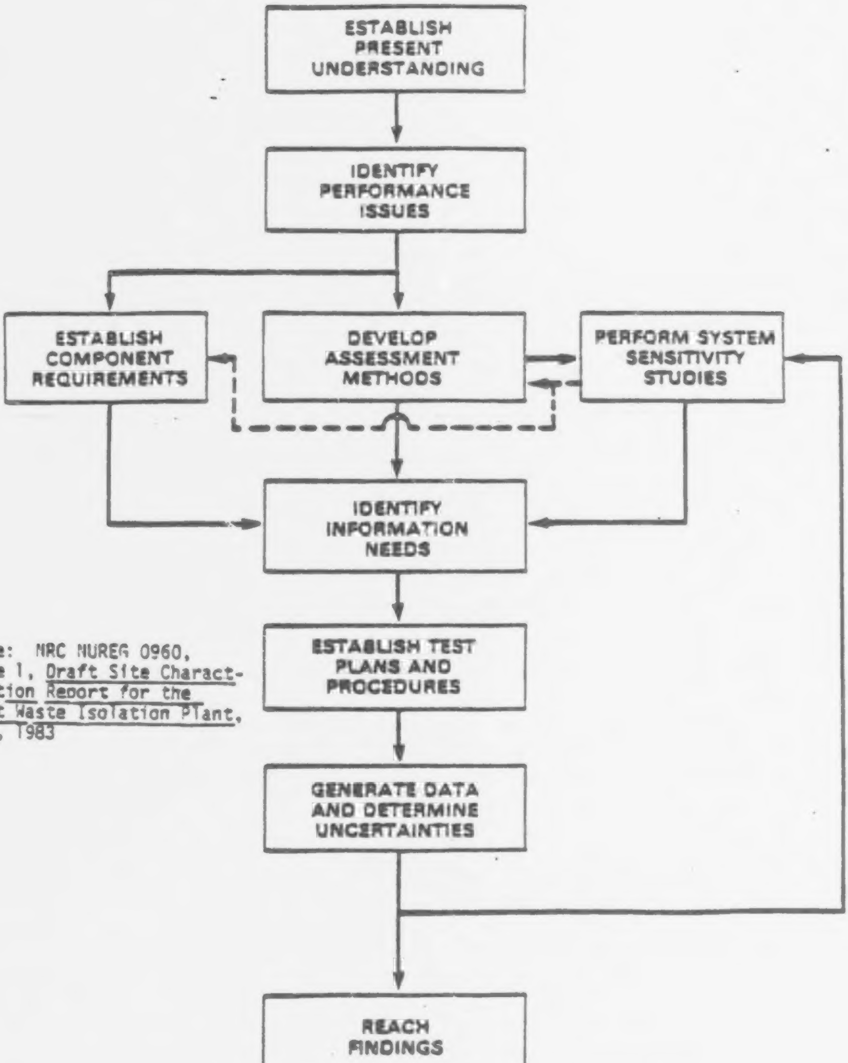
In connection with the need for early conceptual designs, the design process also must support the timely establishment of site specific system component performance requirements. Over the past year the NRC staff has pointed out the need for DOE to establish, as soon as possible, the intended performance requirements for repository system components on a site specific basis. They are needed to determine what information and testing will be necessary for licensing and thus to determine the adequacy of the specific technical programs being conducted at each of the DOE projects.

10 CFR Part 60 gives DOE flexibility, on a site-by-site basis, to propose tradeoffs among system components (natural and engineered). Until at least tentative decisions have been made about intended component performance requirements by DOE, the repository investigation programs may be misdirected and adequate information may not be in hand in time for licensing. NRC's ability to give timely guidance to DOE on licensing information needs may be hindered and in some cases made impossible. Section 5(b)(1) suggests that "top-level design basis, functional requirements, performance measures and performance criteria" are being developed. There is no specific statement, however, of when this will be done.

An iterative design process that contains what the staff consider to be the necessary components is described in detail in Chapter 9 of the BWIP SCA and is illustrated in the attached figure. DOE should also consider the discussion entitled, "g. Conditions of Construction Authorization" in the Supplementary Information for the final licensing procedures (46 FR 13976).

C. The discussion concerning the "all purpose" waste canisters, site specific waste packages, dual-purpose and multi-purpose casks does not adequately explain how the selection and use of such containers would be integrated into the DOE program (pages 2-16, 3-A-19 and 3-E-1 through 5). It appears that site characterization will be planned and conducted using site specific designs that may later be changed as the result of the studies of the "all purpose" canister. No site characterization studies are shown related to the "all purpose" canister. As a result, it appears that no information on performance of "all purpose" canister under actual site conditions will be available to compare the two canister designs on a consistent basis. This should be remedied.

It is essential that "all purpose" canisters be designed to account for site specific conditions (e.g., geochemistry, temperature, pressure, etc.) and so that compliance with the requirements 10 CFR 60 for long-term waste containment and isolation can be demonstrated.


ESTABLISH PRESENT UNDERSTANDING
IDENTIFY PERFORMANCE ISSUES
ESTABLISH COMPONENT REQUIREMENTS
DEVELOP ASSESSMENT METHODS
PERFORM SYSTEM SENSITIVITY STUDIES
IDENTIFY INFORMATION NEEDS
ESTABLISH TEST PLANS AND PROCEDURES
GENERATE DATA AND DETERMINE UNCERTAINTIES
REACH FINDINGS

Source: NRC NUREG 0960, Volume 1, Draft Site Characterization Report for the Basalt Waste Isolation Plant, March, 1983

Figure 1. Site characterization - program logic

Comment #6 Monitored Retrievable Storage

The draft Mission Plan states that the Department will recommend that Congress authorize a process of siting and licensing for a monitored retrievable storage facility (MRS) (page 2-12). Section 141(b) of the Act (42 U.S.C. §10161) requires the Department to submit to the Congress a proposal for the construction of one or more MRS facilities which must include a program for the siting, development, construction and operation of an MRS facility. (The Act has already established a process for MRS siting, as well as for the licensing of the facility by the Commisssion.) DOE recognizes and correctly states these requirements in Section 8, Monitored Retrievable Storage (page 3-8-1, line 2). The statement on page 2-12 should be clarified to accurately reflect the existing statutory framework.

The draft Mission Plan indicates that if it becomes apparent that the first repository will not be ready for operation by January 31, 1998, DOE will seek authorization for construction of an MRS facility (page 2-7). No mention is made of the possibility of early "lag storage" at the repository site, as discussed by Mr. Robert Morgan at the Civilian Radioactive Waste Management Information Meeting on December 13, 1983. Mr. Morgan indicated the potential for two-years storage at the site if repository operation should be delayed. We believe it would be useful for the Department to outline its plans, options, or alternatives for such "lag storage" particularly as it may affect the program with respect to an MRS facility.

In the draft Mission Plan's description of the plan for development of the proposal for one or more monitored retrievable storage (MRS) facilities, it is apparent that design efforts on selected storage concepts are to be based primarily, if not entirely, on generic sites. The Act specifies "site-specific" designs for the MRS proposal [Section 141(b)(4)]. The Act also specifies that the proposal shall include "the establishment of a Federal program for the siting...." of such facilities [Section 141(b)(2)(A). We suggest further clarification of this issue in the description of the siting approach beginning on page 3-8-9. The selected storage concepts may well be relatively site independent from the engineering standpoint. Nevertheless, we believe that the Mission Plan should clearly indicate whether or not the MRS proposal will include proposed actual locations for an MRS facility should it be authorized by Congress.

The plan for development of the proposal for one or more MRS facilities clearly indicates that the preferred storage concept will be developed to a Title I design level of detail. From the NRC staff standpoint, the planned licensing framework for an MRS facility would be a one-stage process as opposed to the two-stage process for construction and operation of the repository. Thus, we agree with the recognition given on page 3-8-12 under "Final Design and Construction" that detailed design information available from Title II design activities must support the safety analysis report that accompanies any application for licensing of

MRS. Under "Licensing" on page 3-B-12, it is estimated that the NRC would require two and one-half years to review a licensing application for MRS. While the two and one half years represents the time for the staff to review a complete, high quality application, it does not provide time to resolve any remaining technical issues, or complete a hearing if one is requested. The review time, of course, is also highly dependent upon the complexity of the selected storage design and its siting aspects. For planning purposes we suggest that the schedules should give recognition to these factors, which could significantly affect the time for licensing.

Comment #7 Interim Storage

We have no comments related to interim storage of spent fuel except to note an error on page 3-D-5, first paragraph. It is our understanding that the rod consolidation demonstration at TVA's Browns Ferry reactor site was delayed and has not been completed as stated.

Comment #8 Transportation Issues

At this stage, substantive transportation planning clearly lags other areas of DOE responsibilities. Questions related to design, use capabilities, certification, ownership and operation of the necessary cask fleet as well as consideration of the appropriate transport modes and mix must be resolved early to permit DOE to establish the level of effort and funding that will be required. This information is also needed to permit NRC to perform its planning, to ensure that we are prepared to give a timely turnaround to what appears to be a heavy workload sometime in the future. We note, for example, that the timeliness of Table III-C-2 would have to be accelerated for early operation of an MRS facility, if Congress should so dictate.

In the draft Mission Plan the Department states (page 3-C-1) that the Act requires transportation activities to "...be performed by private industry to the fullest extent possible and, for transportation activities done as part of the Federal Interim Storage Program, be subject to regulation by the Federal Government" (emphasis added). This statement is misleading in that it gives the impression that the transportation of high-level waste to the repository, as opposed to the Federal Interim Storage facility, will not be subject to regulation by the Federal Government. On the contrary, transportation activities under the Act will be subject to the Department of Transportation regulations contained in 49 CFR Parts 171-177.

We suggest that Table 3-C-1, "Existing Cask Fleet Capacity," on page 3-C-7, be presented in two tables. The first table would show fleet capacity actually available for use (approximately 356 MTU/year), and the second table to show what additional capacity might be available with the NAC/NFS, FSV and NLI-10/24 casks (about 255 MTU/year), subject to posssible modifications and licensing.

It would be more proper to refer to a "Procedural Agreement" between NRC and DOE than a Memorandum of Understanding on page 3-C-12.

II. General Comments

In several places (pages 1-1, 2-5, 3-D-11) the draft Mission Plan states that the Act requires the Department to "... site, license, and operate repositories..." (emphasis added). These statements should be revised to eliminate any suggestion that DOE has the licensing review responsibility for the repository (See Appendix 3).

Throughout the document, the Department refers to a "construction authorization application" (pages 2-9), or a "construction permit" (page 2-10), to characterize the action requested of the Commission on construction authorization for the repository. These references should be revised in order to reflect more precisely the nature of the Commission's licensing action for a high-level waste repository. The process established by 10 CFR Part 60 involves an application for license to receive or possess source, special nuclear, or byproduct material at a geologic repository operations area (10 CFR 60.3(a)). As an initial step in its review of the license application, the Commission may issue a construction authorization for the repository if the requisite standards are met (10 CFR 60.31).

The draft Mission Plan does not address the type, quality, or timing of technical information that will be needed at each stage by DOE to support their license applications and other submittals to the NRC as called for in our regulations and the Nuclear Waste Policy Act. Without detailed descriptions, along with explicit identification of the relevant steps of NRC's licensing process needing the information, we can not advise you on whether we believe the DOE HLW technical program will be sufficient for DOE to accomplish its mission. Also, such information is needed in planning our own research programs. We asume the next draft of the Mission Plan will address these issues appropriately.

Some of the definitions set forth by DOE in the draft Mission Plan (pages 3-A-2 and 3-A-5) are not consistent with those presented in NRC Regulations (10 CFR Part 60, 60.2). In other cases, terms are used without definitions (e.g., conceptual waste package designs - page 3-A-20). DOE staff should coordinate and standardize on the definition and usage of commonly used terms.

In view of the proposed widespread public distribution of the final Mission Plan, we suggest that a Glossary be prepared for abbreviations, definitions and technical terms (e.g., Title I and Title II designs). In addition, citations should be provided for reports and documents refered to in the Mission Plan.

III. Specific Comments

Page 2-5, Second Paragraph

The draft Mission Plan does not address the question of the need for or approach to providing safeguards for spent fuel and high-level waste within the Civilian Radioactive Waste Management Program (e.g., accountability, physical protection, transportation routing, etc).

Page 2-9, Last Paragraph

The Secretary's recommendation of the first repository site to the President must include comments made by the Commission concerning the final EIS submitted by DOE with this recommendation, and preliminary comments of the Commission concerning the extent to which the at-depth site characterization analysis and the waste form proposed for such site seem to be sufficient for inclusion in any application to be submitted by the Secretary for licensing of such site as a repository. (NWPA Sections 114(a)(1)(D) and 114(a)(1)(E). Recognition of and provisions for this interaction must be part of DOE's planning.

Pages 2-12, First Paragraph

It is not clear what the "TEF permanent surface construction" would include. The schedule shows TEF testing occuring before the completion of such construction. The NRC staff need to know what is planned to be able to understand and comment on this approach.

Page 3-A-5, Second Completed Paragraph

We believe that the word "requirements" in the 8th line should read "objectives."

Page 3-A-9, item 4c

Affected Indian tribes are to be consulted and cooperated with on the same level as State and local governments, not instead of them. Consequently, we suggest changing the word "or" to "and" as indicated in Appendix 3.

Page 3-A-9 Paragraph d

Add - "and licensed by the NRC."

Page 3-A-10, Paragraph e

DOE should acknowledge that a conceptual design is necessary at the time of the site characterization plan. This is required by Section 113(b)(1)(C) of the NWPA and by 10 CFR 60.11.

Page 3-A-13, Second Paragraph

There are additional rock properties which need to be considered, such as, seismotectonic stability, hydrodynamic dispersion, matrix diffusion, hydraulic continuity, and hyraulic gradient.

Page 3-A-18, First Paragraph

The plan should clarify the purpose of reporting the preliminary performance assessments in the Environmental Assessments. The performance assessments would appear to be highly speculative due to the absence of geologic data for key parameters affecting performance prior to detailed site characterization.

Page 3-A-18, Second Paragraph

These system requirements are needed now. This has been a key issue in the repository technical program area (See Comment 5).

Page 3-A-19, First Paragraph, Line 11

To our knowledge the conceptual waste package design for salt, basalt, and tuff have not as yet adequately defined the component performance requirements (See Comment 5).

Page 3-A-19, First Paragraph, Line 21

Although numerical performance objectives in 10 CFR Part 60 for the engineered barriers are established only for "anticipated processes and events," the overall system must meet the EPA standard even for unlikely events and processes. Therefore, the final Mission Plan should address the approach that DOE intends to take in considering the contribution of waste package performance toward overall performance of the repository for unanticipated or low probability events and processes, as well as under "expected repository conditions."

Page 3-A-25, First Paragraph, Line 10

DOE should clearly define what it considers to be an adequate iterative process for repository design (See Comment 5).

Page 3-A-35, Figure 3-A-5

The December 1983 date shown for issuance of the final DOE guidelines should be amended.

Page 3-A-37, Last Two Paragraphs

DOE should allow sufficient time between issuance of the SCP and sinking of an exploratory shaft to receive and consider comments on the SCP, unless other means are provided to advance plans and other requisite information on the initial steps of shaft construction and testing to NRC and affected parties before SCP's are issued. In any case, given the long lead times associated with the planning, construction and testing of exploratory shafts, selected information will have to be provided and consultations carried out well in advance of SCP's as outlined in letters to each of the projects from the NRC. (Examples-Letters, on NTS, from Coplan, NRC to Veith, DOE, dated April 14, 1983; on SALT, from Miller, NRC to Neff, DOE, dated July 7, 1983).

Page 3-A-38, First Two Paragraph

The basis for the estimate of 8 to 27 months for in-situ testing is not given or referenced. It is not clear in the paragraph if this includes sinking shafts

DOE indicates that adequate testing to support a draft EIS on the site to be recommended for development as a repository will be completed in September 1989, and that a site recommendation will be submitted to the President in October 1990. NRC would prefer it if DOE chose to clarify whether it intends to continue site characterization activities after the recommendation has been submitted to the President, describe the extent and nature of such activities, and explain the rationale for these continued activities in light of Sections 114(a) and 114(f) of the NWPA.

Page 3-A-44, Second Paragraph

DOE asserts that Congress had decided that site nominations are not a major Federal action and do not require an Environmental Impact Statement (EIS). Although it is true that the site nominations do not require an EIS under Section 112(e) of the Nuclear Waste Policy Act, the Congress did not make a determination that such an activity does not constitute a "major federal action." In fact, language to that effect was specifically deleted from H.R. 7187, the final House version of the Act, by the adoption of an amendment introduced by Representative Breaux. 128 Cong. Rec. H 8197 (daily ed. September 30, 1982).

Page 3-A-43 and 3-A-44

Some caution is called for in the statement that technical issues can be resolved without delay in the licensing process because of the prelicensing interaction between DOE and NRC. Regardless of efforts to resolve technical issues in the prelicensing stage, these issues will continue to be subject to challenge in a licensing proceeding. In that sense, such issues would not be "resolved" despite the interaction described in the text.

Page 3-C-12, item d

Treaty and other obligations with respect to Indian tribes were omitted from the first paragraph as an area of potential institutional impediments. Indian tribes should be incorporated into the wording as shown on pages 3-C-12 and 3-3C-13 (See Appendix 3).

Page 1-3

We note the important program goal "State, Local Government and Tribal Consultation and Cooperation" is absent from the program goals. We believe that the Department should consider "State, Local Government and Tribal Consultation and Cooperation" as the fifth program goal necessary to achieve its goal to accept commercial high-level radioactive waste for safe management, storage, and permanent disposal on a firm schedule, beginning not later than January 31, 1998.

Appendix 1 Initiation of Construction at a Collocated Test and Evaluation Facility

The interpretation contained in the draft Mission Plan of the TEF provisions of the Nuclear Waste Policy Act of 1982 (the Act) would allow subsurface construction of the TEF to begin after a repository site has been designated under Section 115 of the Act (42 U.S.C. 10135), but before the Commission has issued a construction authorization. According to the draft Mission Plan, only the construction of surface facilities in support of the TEF must wait until after the construction authorization is issued. In our opinion, the legislative history of the TEF provisions of the Act supports the conclusion that no construction, surface or subsurface, can begin until after the Commission has authorized construction at the repository site.

Under Section 305(b)(1)(A) of the Act (42 U.S.C. 10225), a TEF may not be collocated at any repository site or any site that has been recommended for site characterization unless the site selection and development of the facility is undertaken in accordance with the procedures and requirements established in the Act for repository sites. Furthermore, Section 305(b)(1)(B) provides that construction of surface facility for a TEF cannot begin before the Commission issues a construction authorization for a repository at the site involved. Although this paragraph specifically refers to a "surface facility," it must be construed within the context of the legislative intent and history of Section 305 of the Act.

Section 305 originated in the final compromise bill in the House, H.R. 7189 (designated as Section 306 in that bill). The intent of Section 305 was to prevent a TEF from being used to prejudice the repository selection process, i.e., to prevent the TEF from becoming a "back door" repository. Remarks of Rep. Bouquard, (128 Cong. Rec. H 8174) (daily ed. September 30, 1982). In this regard, the construction of the subsurface component of the TEF could prejudice repository site selection to a larger degree than the surface facility would. To avoid the potential for bias, Section 305 would totally prohibit onsite construction - i.e., would even prohibit construction of surface facilities - until a construction authorization for the repository was issued by the Commission. Rep. Bouquard recognized that this was not the ideal approach for an R&D program, but noted that the Secretary of Energy still had the discretion to pursue a TEF that was not collocated at a repository site, and under Section 217(f)(2) of the Act (42 U.S.C. 10197), would not be subject to Commission licensing. (128 Cong. Rec. H 8174) (daily ed. September 30, 1982).

Further evidence of the Congressional intent to prohibit onsite construction of the TEF, both surface and subsurface, until the Commission has issued a construction authorization for the repository site, is provided by the discussion on an amendment introduced by Rep.

Swift to clarify the intent of Section 305(b)(1)(B). (128 Cong. Rec. H 8590) (daily ed.-November 30, 1982). As noted earlier, Section 305(b)(1)(B) prohibits the construction of a surface facility for a TEF prior to the issuance of construction authorization for the repository site. (Emphasis added). Rep. Swift's concern was that excavation for a TEF at a candidate site prior to the issuance of a construction authorization would give the site a greater chance of being selected than another site at which there was not a TEF prior to the issuance of a construction authorization for the repository. The floor managers of the bill persuaded Rep. Swift to withdraw the amendment by assuring him that clarification was unnecessary because the existing language of Section 305 precluded the excavation of a subsurface TEF prior to the issuance of a construction authorization for the repository. Rep. Ottinger, one of the primary architects of Section 305, provided the following explanation:

> The language of Section 306(b)[1/] says quite clearly that if the test and evaluation facility is to be located at any candidate site or repository site - even just a candidate site, it applies - site selection and development of such facilities shall be conducted in accordance with the procedures and requirements established in Title I.
>
> As Chairman Fuqua has indicated, that would clearly require a construction authorization prior to excavation of a facility. The way I look at subsection (b), it is an additional requirement that says one cannot even locate surface facilities at that facility without getting a construction authorization for a repository.
>
> So I think that subparagraph (B) is an additional requirement; quite clearly, if you are going to have a facility there, under Title I which is made to apply, the contruction authorization would be required.
>
> 128 Cong. Rec. H 8591 (daily ed. November 30, 1982).

[1/] Redesignated as Section 305(b) in the Nuclear Waste Policy Act of 1982, Pub. L. No. 97-425.

Appendix 2 Limited Work Authorization for Site Characterization and Repository Construction Activities

In several instances, the draft Mission Plan refers to the Commission granting the Department a Limited Work Authorization (LWA) for site preparation and repository construction activities before a construction authorization is issued (See pages 3-A-26, 3-A-27, 3-A-38, and 3-A-40). However, in a later reference to a LWA (page 3-A-43) DOE notes that the Commission regulations in 10 CFR Part 60 "provides no specifics as to whether or not the NRC would accept an application for a Limited Work Authorization." The Department then states that an LWA request would be submitted as part of the license application.

The procedures in 10 CFR Part 60 do not provide for an LWA. Specifically, 10 CFR 60.3(b) prohibits DOE from commencing construction until it obtains a contruction authorization from the Commision. "Commencement of Construction" is defined in Part 60 as the clearing of land, surface or subsurface excavation or other substantial actions that would adversely affect the environment of the site. However, the definition would allow the Department to pursue certain types of activities, such as activities related to site characterization and other preconstruction monitoring and investigation necessary to establish background information related to the suitability of the site. However, this does not constitute a LWA and our existing regulations do not authorize the consideration or the granting of a LWA.

In the development of the 10 CFR Part 60 rulemaking, the Commission explicitly considered the type of activities that would be permitted prior to the Commission's initial licensing decision, and did not provide for a LWA. Under the Commission's Proposed General Statement of Policy, which outlined the procedures for the licensing of geologic repositories for high-level radioactive wastes, only surface exploration combined with some test borings would have been permitted prior to the Commission's issuance of a construction authorization or a provisional construction authorization (43 FR 53869, November 17, 1978). After further review of this issue, the Commission determined that exploration and in-situ testing at depth should be allowed prior to the issuance of a construction authorization (44 FR 70408, December 6, 1979). In arriving at this position, the Commission noted that the incremental costs for these activities would be small, in the context of overall project costs for a repository, and implied that such increased financial investments and institutional commitments were warranted only because of the substantial improvement in the quality of available data that could be expected. While the character of activities under an LWA is unclear, there would appear to be no comparable benefit in terms of improved data for licensing.

In addition, in response to a question on the advisability of a LWA provision raised at Congressional hearings on the Nuclear Waste Policy Act, both Commissioner Ahearne and Chairman Palladino stated that they did not support the LWA concept, at least for the first repository. Nuclear Waste Disposal Policy: Hearings on H.R. 1993, H.R. 2881, H.R. 3809, and H.R. 5016 before the Subcommittee on Energy Conservation and Power of the House Comm. on Energy and Commerce, 97th Cong., 2d Sess. 553 (1982). See also H.R. Rep. No. 411 Part 1, 97th Cong., 1st Sess. 58 (1982) ("the Commission does not support interim licensing authority. First, this facility is too critical to waive the hearing. It is the first of its kind. Second, getting state, local, and general public acceptance is the hardest task for this facility. Interim licensing strongly undercuts building the needed acceptance.")

Appendix 3 Suggested Changes

Page 1-1, Second Paragraph

In response to this situation, President Reagan signed Public Law 97-425, the "Nuclear Waste Policy Act of 1982" on January 7, 1983. The Act requires the Department of Energy to site, apply for a license from NRC and operate repositories for spent nuclear fuel and high-level radioactive waste. The program developed by the Department to fulfill the requirements of the Act is described in this Mission Plan.

Page 2-5, Last Paragraph

The Nuclear Waste Policy Act of 1982 also requires the Department to initiate the process of selecting a second geologic repository site through the phase of Presidential recommendation to Congress. After identifying a site, and upon Congressional approval, the Department will proceed to apply for a license from NRC for the site and construct a second repository. The Act does require that a second repository be in operation before the loading.

Page 3-A-9, item 4c

c. Establish and maintain effective mechanisms for the involvement of State and local government and affected Indian tribes in the repository program.

Page 3-C-12, item d

Institutional impediments in nuclear waste transportation will be identified and resolved in four specific areas: Federal regulation; State and local regulation; treaty and other obligations with Indian tribes and public attitudes and perceptions.

Page 3-C-13 Line 3

Commmission and perhaps the courts. However, the Department can take the initiative to identify and resolve the concerns of State and local officials and affected Indian tribes which give rise to regulatory inconsistencies.

Page 3-C-13, Last Paragraph

As previously noted, the Department plans to develop material and provide forums for information exchange on nuclear waste transportation. These efforts will consist of information development and dissemination to the general public, State and local officials, affected Indian tribes, the media and other interested parties. Some specific activities envisioned include the development and maintenance of a nuclear transportation data base for access by the public; development of a speakers bureau as a resource for public meetings; and the development of an information network drawing upon the expertise and knowledge of individuals from government, industry and the general public. These efforts will also include the solicitation of public, State/local official, and Indian tribes, comments on the Department's civilian nuclear waste transportation program in order to identify real or perceived program weakness or information gaps that need to be addressed.

Page 3-D-11, Line 4

...filings of such a request, however an examination of the request by the Department must find the applicant's case convincing before funds will be expended in advance of contract signing. The schedule calls for completion of design, application for licensing (where applicable) and construction.

CP&L
Carolina Power & Light Company
P. O. Box 1551 • Raleigh, N. C. 27602
(919) 836-6382

SHERWOOD H. SMITH, JR.
Chairman/President

March 12, 1984

Ms. Debbie Martin
Room B-374
Rayburn House Office Bldg.
Washington DC 20515

Dear Ms. Martin:

As requested, I am forwarding the attached response to questions asked in Ms. Marilyn Lloyd's letter of February 24, 1984.

Sincerely,

Sherwood H. Smith, Jr.

SHSjr:bas

Attachment

Responses to Questions
Submitted to Carolina Power & Light Company
by the Subcommittee on Energy Research and Production
Committee on Science and Technology
U.S. House of Representatives

Repository Schedule

1. We are concerned that the Department is too lax in its commitment to meet the deadlines specified in the Waste Act. Delays always seem to escalate costs. What is the utility industry's view concerning these deadlines?

The utility industry is concerned over the schedule slippage that has already occurred; e.g., the DOE site selection guidelines were to have been issued by July 7, 1983 but still are not finalized. The threatened future slippages of other legislated dates are of considerable concern. The recent draft of Volume I of the DOE Mission Plan indicates a delay in the recommendation to Congress by the President of the first repository site from March 31, 1987, as mandated by the Act, to December, 1990.

We support the need to proceed through the process called for in the Act with the full recognition of all concerns, but we believe that equivalent emphasis must be applied to satisfy the schedule mandated by the Act. Having the first repository by 1998 is very important. To reach this goal, the many intermediate steps must be achieved on a timely basis. DOE should be encouraged by Congress to move aggressively to re-establish the schedule to match the dates prescribed in the Act and Congress should monitor progress against the backdrop of the timetable as a "vital sign" of the health and condition of the program.

2. What activities do you believe DOE could accelerate in order to help meet the deadlines?

In the EEI/UNWMG comments to DOE on Volume I of the Mission Plan, it was suggested that time could be saved by:

- Construction of exploratory shafts in parallel at the three sites selected for characterizations rather than in series as indicated.
- The two years shown for exploratory shaft construction is probably too long for at least some sites, as is the period for testing.
- It should be possible to accelerate the preparation of the Draft Environmental Impact Statement (DEIS) by completing most of the work prior to the end of testing, thus shortening the period between the end of testing and issuance of the DEIS.

Another possibility would be to obtain necessary state and local permits as far in advance as possible for all potential sites even though some of these may be for sites that are later deleted from the list of candidate sites.

LWR Extended Burn-up

3. Exxon Nuclear reportedly plans to demonstrate a "significantly higher" burn-up fuel early next year. If they can do it, why can't other vendors do it without continued Federal funding?

Our understanding is that all vendors of nuclear fuel are actively pursuing technology that will gradually increase the burn-up achieved by such fuels in the future. The payoff for this effort is over a very long term and will not be achieved without a substantial base of technical information and data to assure very high reliability for the high burn-up fuels. A continued role by the Federal Government will provide a strong research capability that would permit obtaining data at an earlier date than will occur otherwise. Thus, the Edison Electric Institute supports a continued Federal program for high burn-up fuel.

Despite the willingness of nuclear fuel vendors to demonstrate higher burn-up fuel, the technology will not progress rapidly and gain wide acceptance without Federal funding to complete the program that was initiated in this area. The reason for this is a matter of prudent risk taking on the part of electric utilities and nuclear fuel vendors.

One incentive for high burn-up fuel appears to be the possible savings associated with the reduction in the volume of spent fuel generated and requiring disposal. Less spent fuel will have some, yet unidentified, savings in the nuclear waste disposal activities being carried out by DOE pursuant to the Nuclear Waste Policy Act of 1982. As high burn-up fuel technology is developed, accepted and fully deployed, the effects of spent fuel volume reduction will be seen in the waste program in terms of cost reductions at that time, that is, in the future. Due to the uncertainty associated with the research and development nature of the high burn-up fuel program, it does not appear appropriate to adjust today's waste disposal rates to reflect high burn-up fuel cost savings, that may or may not occur at some time in the future. Similarly, the Nuclear Waste Fund should not be used as a source of funding for the high burn-up program.

Since it is the Federal Government that will ultimately control the distribution of any benefits through waste disposal rates, with Federal funding the risk remains in the proper hands. Furthermore, with Federal funding the technology will be developed, accepted and deployed faster and those benefits that can be enjoyed will be available earlier to the electricity consumer.

Remedial Action

4. Do you believe that DOE is undertaking appropriate activities to transfer both costs and technology to the utility sector for the decontamination and decommissioning (D&D) of the Shippingport facility?

Once the decision to decontaminate and decommission the Shippingport Atomic Power Station was made, DOE selected the method of complete and immediate dismantling and removal of the station from the site. The electric utility industry did not, of course, participate in this determination, and it is not clear that they would have selected the same method of decommissioning. However, given that DOE is proceeding in this manner, some valuable information can be derived from the activity and we urge DOE to make all information available to the public and the industry on the efforts. We do not believe it appropriate to seek private sector funding for this program that the Federal Government decided to carry out for its own reasons.

West Valley

5. Does EEI have any involvement with the West Valley Demonstration Project? Do you believe this project still provides a useful demonstration for solidification technology considering that there are no commercial reprocessors?

While the Edison Electric Institute has no direct involvement with the West Valley Demonstration Project, we believe that it is appropriate to continue the activity even though there are no commercial reprocessors in the U.S. and it is unlikely that there will be in the foreseeable future. The West Valley nuclear fuel reprocessing plant operated for six years and was eventually abandoned by its operators when they were faced with prohibitively expensive modifications to secure Federal approval to resume operations. Although the stored high-level waste probably could have been kept on site indefinitely without endangering the nearby population, the West Valley plant is one of those facilities used by the opponents of nuclear energy to make their case that the technology is a failure. Its clean up is very important to removing one of the controversial issues that obstructs the future of nuclear energy development in the nation. In passing the West Valley Demonstration Act the Federal Government recognized its contributions to the situation at the plant and agreed to take a major role in performing the clean up activities. We support the legislation and urge that it be carried out to completion under Federal funding in cooperation with New York State.

MRS Facility

6. It is believed that in 1998 the Department of Energy will begin accepting spent fuel for storage in a monitored retrieval mode rather than a permanent mode. What difference will this make to the utility industry?

The electricity consumers of those utilities with nuclear programs are now, and will in the future, pay the full cost of the nuclear waste disposal program. It is in the best interest of these consumers for the overall program to be run efficiently, effectively and timely. If the Department of Energy and the Congress determine that a monitored, retrievable storage facility is preferred as an essential step in the program or that it will achieve greater cost effectiveness for the overall program, then it will be supported by the utility industry. A primary concern of the industry is that the legislated date of 1998 be held firm as the date for DOE to start taking spent fuel and that no additional costs for storage expansion at reactor sites are to be imposed on the electricity consumers after that date. Our preference is for a firm schedule to be established and met to assure that the first nuclear waste repository is available by 1998.

**Westinghouse
Electric Corporation**

**Advanced Power
Systems Divisions**

L P Duffy
General Manager
Waste Technology Services Division

Box 10864
Pittsburgh Pennsylvania 15236-0864

March 23, 1984

Marilyn Lloyd, Chairman
Subcommittee on Energy Research
and Production
U.S. House of Representatives
Committee on Science & Technology
Suite 2321 Rayburn House Office Building
Washington, DC 20515

Dear Ms. Lloyd:

I appreciated the opportunity to testify before the Subcommittee on February 9, 1984. Attached are responses to the questions posed by the Subcommittee to provide supplementary information for the record. I hope you will find this information useful in your review of the Department of Energy budget request.

Sincerely,

Leo P. Duffy

Attachment

March 23, 1984

Subject: Questions for Subcommittee regarding February 9, 1984 Testimony

Question - (a) Does Westinghouse have any high level waste or spent fuel to be disposed of in a repository?

(b) Does Westinghouse believe that the deadlines set forth in the Waste Act are reasonable and can be complied with by DOE?

Answer (a) - Westinghouse has no high level waste or spent fuel to be disposed of in a repository.

Answer (b) - Westinghouse believes that the deadlines specified in the Waste Act generally meet the needs of most electric utilities who operate nuclear power plants. As indicated in our testimony, we believe that the technology to achieve the schedules specified in the Act is available. Events since the passage of the Waste Act have emphasized, however, the importance of institutional issues as critical path items in terms of meeting the schedules envisioned in the Waste Act. These issues, in our judgment put the schedules set forth in the Waste Act in jeopardy. We believe that the lessons learned in this area during the time since passage of the Waste Act are worthy of further study by the Department of Energy and that a plan of action should be developed to deal specifically with institutional issues. Further, given the schedule slippage which has already occurred in the program, it would be prudent for Congress and the DOE to raise the Monitored Retrievable Storage Program in status from a contingency study program to a full parallel effort.

Question - West Valley - is the work at West Valley being accounted for so as to provide an easy reference to the costs of solidification of wastes, as distinct from decontamination and first-of-a-kind R&D?

Answer - Yes, the program that Westinghouse is carrying out for the Department of Energy at West Valley is planned and managed on relatively detailed work task basis. Basically each task is assigned a budget and actual expenditures are accounted for versus this budget. The breakdown of tasks will allow decontamination to be relatively easily accounted for separately from the solidification system development.

Question - Commercial Waste R&D Programs — Does Westinghouse support the Department's program for the development of second generation waste forms? If so, why?

Answer - Westinghouse believes that the waste forms, principally borosilicate glass, planned for use at West Valley and Savannah River are adequate and meet present requirements. In the future requirements may change or the U.S. may move toward commercial nuclear fuel reprocessing. For these reasons, we believe that a modest program evaluating alternative waste forms or alternative, more economical processing techniques is prudent.

Question - Commercial Waste R&D Programs — You mention on page two of your testimony that Westinghouse is developing waste technologies. How much money is Westinghouse spending annually on R&D for nuclear wastes?

Answer - Westinghouse is engaged in a number of nuclear waste related activities ranging from services provided to electric utilities for low level waste processing through its activities performed for the U.S. DOE on high level waste solidification. Since high level waste and spent fuel management is ultimately the responsibility of the government the bulk of R&D associated with these areas are carried out as part of DOE programs. Overall waste related development expenditures by Westinghouse are on the order of two and one-half million dollars per year.

Question - What level of effort, over what period of time, would be required to determine the technical feasibility and estimated cost of multipurpose casks that could be used for spent fuel storage, transportation and disposal? What tests are required to determine the limiting design characteristics for cask emplacement in a geologic repository?

Answer - The principal technical feasibility issue associated with the use of multipurpose casks has to do with the choice of cask material. Two practical materials, from a cost and performance standpoint, are low carbon steel (either cast or forged) and cast ductile iron.

With respect to carbon steel, the following engineering judgments can be made based on our repository waste package design work, spent fuel dry storage experience, spent fuel shipping experience, and contacts with the NRC.

- A carbon steel cask will be acceptable for spent fuel storage at the reactor or at a Monitored Retrievable Storage (MRS) facility.
- A carbon steel cask will be difficult as a spent fuel shipping cask. Shipping the carbon steel cask within a suitably designed, reusable container fabricated of stainless steel is feasible, but has not been demonstrated.
- Preparing the cask for disposal by performing an acceptable cask closure weld is feasible, but the technique should be demonstrated and the effect of the welding process on corrosion properties should be tested.

With respect to the use of ductile iron, the following judgments can be made.

- A ductile iron cask will be acceptable for spent fuel storage.
- Ductile iron casks may be licensable under NRC groundrules as shipping casks.
- The feasibility of making a satisfactory cask closure for disposal is not certain. Closure design studies, weld development, and corrosion testing must be performed to establish feasibility.

Based on the above engineering judgments, we conclude that the use of a multipurpose cask fabricated of carbon steel is technically feasible, whereas additional testing is required to establish the technical feasibility of a ductile iron cask. A ductile iron cask is attractive because it has the potential for lower cost and, because of its better neutron attenuation, lower weight. To establish and/or confirm technical feasibility and costs, engineering and development programs are necessary in the following areas:

- Engineering design studies to develop conceptual designs of carbon steel casks compatible with the use of a reusable shipping container, development and evaluation of alternative cask sizes and configurations, design of detailed cask closure configurations for testing, and development of cost estimates.
- Test programs to demonstrate closure weld feasibility reference welding method (an electroslag technique), for both carbon steel and ductile iron.
- Preliminary corrosion testing of weld zone and heat affected zone material in groundwaters representative of the three current candidate geologies.

We would estimate the cost of a program covering the above areas to be in the range of three to five million dollars. The program would require roughly three years with the first two efforts performed in parallel over a 20-month period and the third item commencing roughly at that time.

Westinghouse has performed sufficient repository waste package design and analysis work to reasonably define the limiting thermal, structural, shielding, weight, and corrosion characteristics of casks suitable for emplacement in a geologic repository. We believe that no testing is required to confirm the feasibility of this type of emplacement. However, testing is desirable to verify analysis models and to narrow the uncertainty band of some of the parameters used in the analysis models. Some areas of testing include:

- Heat transfer with consolidated fuel rods (applicable to any waste package design as well as interim dry storage).
- Achievable density and thermal conductivity of tunnel backfill material that will surround emplaced disposal casks.
- In-situ measurement of host rock thermal conductivity and heat capacity.
- Minimum wall thicknesses required to prevent crushing under lithostatic or hydrostatic pressure for casks with various cross sectional shapes.
- Initiation of long-term corrosion tests under closely simulated repository conditions.

Question - It can be claimed that the most important step in the West Valley demonstration project is the ceramic melter which encapsulates the high level waste material. At this time what degree of certainty do you have that this process will operate successfully? What amount of development will increase your confidence level?

Answer - Westinghouse has a high level of confidence that the process will operate successfully. This confidence is based on the extensive experimental work at the Department of Energy's facility at Savannah River and at the Battelle Pacific Northwest Laboratories (PNL). At present there are two operating melters at PNL undergoing demonstration testing using non-radioactive materials. A third melter for demonstration testing using limited amounts of radioactive materials is scheduled to go into operation shortly. In addition to the U.S. data, surveys and evaluations of world melter technology have been conducted to ensure that the design used at West Valley incorporates that experience base. The Component Test Stand, now under design at West Valley, will demonstrate the important operations of the off-gas system, material feed system, and canister handling system during a one and one-half year cold (non-radioactive) test program. The development and testing work now underway and planned is judged to be very adequate to assure successful operation of the ceramic melter at West Valley.

Question - What is the defueling schedule for the damaged reactor at Three Mile Island Unit 2?

Answer - Westinghouse is under contract to General Public Utilities - Nuclear to perform the defueling of the damaged core at Three Mile Island II. Defueling operations are presently scheduled to begin in mid-1986 with the total process expected to take 6 to 18 months, depending on the system and procedure used to defuel the reactor core.

March 30, 1984

Ms. Nancy Jeffery
Subcommittee on Energy Research
and Production
B-374 Rayburn House Office Building
Washington, D.C. 20515

Dear Ms. Jeffery:

Enclosed are Mr. Warren Chernock's answers to the subcommittee's questions regarding the high nuclear fuel burnup program. We expect to forward Dr. Storr's answers in the very near future. Please excuse the delay.

If you have any questions, please give me a call on (202)-429-9180.

Sincerely yours,

Enclosure

Question No. 1

Please advise the subcommittee on the amount of additional effort, money, schedule, and facilities necessary to complete the Extended Burnup Program to the extent you feel is necessary.

Response

The following effort appears necessary to complete the Extended Burnup Program.

As recommended in my testimony, the following objectives should be pursued:

1. Continuation of the current program but with long term funding stability and increased workscope flexibility.
2. Reassessment of program goals to determine proper burnup targets in light of current and future requirements and foreign competition.
3. Initiation of new program elements consistent with new goals, particularly with respect to the impact of the Nuclear Waste Policy Act.
4. Encouragement of logical program extensions which maximize the information gained from large program expenditures already made.

Projected costs for this program are:

—	FY1985 FY1986	$12M $10M	Continuation of ongoing programs, examination of irradiated fuel, burnup optimization, plans for new irradiations
—	FY1987 through 1990	$ 4M/year	Irradiation and surviellance
—	FY1991	$10M	Hot cell examination and test reactor experiments

Within the above framework, additional details include:

a. Complete the irradiations already initiated to the levels of burnup appropriate to the objectives established at their initiation.

b. On the bases of results of item 2, above, initiate new irradiations and extend existing irradiations to the optimum burnup targets.

c. Attempt to maximize existing and future irradiation data via additional measurements to establish a more statistical data base. For example, additional in-reactor corrosion data on high burnup zircaloy cladding could be obtained.

d. Perform destructive hot cell examinations on irradiated fuel, as necessary, to establish burnup capabilities consistent with item 2.

e. Ramp test fuel segments in the Power Burst Facility at Idaho. If this is not possible, prepare these segments for ramp testing in Sweden, Norway or the Netherlands.

Question No. 2

With the amount of data now in hand, why is it inappropriate to consider a program in which the costs are either shared with DOE or totally borne by industry?

Response

As indicated in my testimony, the amount of data now in hand will be only partial achievement of program objectives. It is inappropriate to consider a program in which the costs are either shared with DOE or totally borne by industry for the following reasons:

- At program initiation, agreements were made for front-end contributions from the fuel vendors in the form of cost-shared programs, contributed information from prior programs and, in some cases, the disclosure of proprietary designs. These contributions were considered justifiable because of the expected completion of the overall objectives. Thus, the fuel vendors have already contributed their cost-share with full anticipation of program completion.
- Prevention is preferable to mitigation.
  - Prevention: Completion of program objectives could result in discharge of 40 percent less fuel from commercial nuclear power reactors. Even greater reductions in the amount of discharged fuel are possible via logical program expansions.
    - Less fuel will be transported.
    - Less fuel will require storage.
  - Mitigation: The Nuclear Waste Policy Act of 1982 provides for Government interim storage and permanent disposal of discharged spent fuel.
  - Millions of dollars of Government funds are likely to be expended on development of mitigation whereas the current DOE budget submission provides zero funding for prevention.
  - It appears ludicrous that DOE is prepared to expend large sums of taxpayer and utility ratepayer funds to accommodate discharged spent fuel but is unwilling to expend funds on a program capable of substantial reductions in the amount of spent fuel to be discharged, transported and stored in Government facilities.
- This program will save the taxpayer money
  - The General Accounting Office (November 18, 1981, report of cost benefit studies) indicates that the cumulative benefit to the general public of fully implementing extended burnup would be approximately $13 billion (1981 dollars) through the year 2000.

Question No. 2 (Continued)

  - Considering the small cost of continuing and expanding the program, the cost benefit ratio is on the order of 1:300.
  - This extremely low cost-to-benefit ratio is considerably smaller than that typically encountered in Government-funded development programs.

- This program will save the Government money.

  - About 40 percent less fuel will be discharged with current program goals.
  - Even greater reductions in the amount of spent fuel discharged could be achieved by adopting the higher burnup goals being considered by the Europeans.

  Substantial financial benefit should be derived by DOE in planning and sizing facilities necessary to accept spent fuel required by the Nuclear Waste Policy Act when the number of discharged fuel assemblies is reduced substantially.

- This program is not likely to be fully implemented without Government support because there are substantial disincentives for the fuel vendors.

  - Bases for presumptions that fuel vendors or utilities would complete and expand the program to meet new targets and maintain world leadership in this area are not clear.
    - The fuel vendor has no incentives since fewer fuel assemblies are fabricated per year while warranty risks may be increased with higher burnups.
    - Not only is the fuel vendors's total reload business diminished, but also there is reduced potential for achieving economics of scale during fabrication.
    - In most instances, the economic benefits associated with high burnups and longer fuel cycles must be passed on the ratepaying public and, thus, there is no incentive for utility funding to complete or expand the program.

Department of Energy
Washington, D.C. 20585

March 21, 1984

Honorable Marilyn Lloyd
Chairman
Subcommittee on Energy Research
and Production
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Madam Chairman:

Attached are the answers to questions on the Nuclear Waste Fund you sent after Michael J. Lawrence's appearance February 9 before the Science and Technology Subcommittee on Energy Research and Production.

Questions pertaining to Remedial Action, Shippingport, West Valley, Three Mile Island R&D were sent to you on March 15, 1984.

If you have any questions, please call Diana Diamond or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H. Pretorius for
Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Ms. Nancy Jeffery

POST HEARING QUESTIONS

FEBRUARY 9, 1984

SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

WITNESS: MICHAEL J. LAWRENCE

QUESTION: The budget justification book states that the Test and Evaluation Facility "is the only non-generic research and development activity in the Waste Fund's repository program," but isn't it true that the site characterization process is simply another name for a research and development program to define the geologic media and natural conditions?

ANSWER: The Department believes that the site characterization process has moved beyond the research and development phase. The program is essentially in a technology development and engineering phase.

QUESTION: Does DOE plan to notify Congress each time it attempts to escalate the 1 Mil/KW hour charge for inflation or otherwise? If not, what statutory authority allows DOE to make such adjustments without notice?

ANSWER: Section 302(a)(4) of Public Law 97-425 requires the Secretary to annually review the adequacy of the fees being paid into the Nuclear Waste Fund and propose any required adjustments to Congress for approval. The Department is following this process as specified. The initial fee adequacy analysis has been completed and was reported in DOE/S-0020/1 of July 1983. The next annual update of the fee adequacy analysis is underway and is expected to be completed by July 1984.

The discussion in our Fiscal Year 1985 budget submission reflected a preliminary budgeting concept we were considering for reconciling our expected out year expenses with our revenue projections. It did not constitute a proposal to change the 1-mill fee.

QUESTION: The budget justification book states that the site evaluation process is being extended to ensure "higher certainty of data and greater conservatism." Why can't DOE stick to the schedule and use the site characterization process to develop higher certainty and greater conservatism?

ANSWER: Phase 2 of the repository siting process, which we define as the time between the recommendation to the President of three sites for site characterization and the selection of one site for the first repository, involves land acquisition, construction of exploratory shafts and in situ testing, data collection and analysis. The Act provides only two years between recommending three sites (January 1, 1985) and selecting one site (March 31, 1987). This is insufficient time to complete these activities. The Department plans to meet the January 1, 1985, date of recommending three sites for "site characterization," but does not believe it can meet the March 1987 date. However, the Department believes that it can meet the 1998 milestone for acceptance of waste from the utilities.

QUESTION: Is the Department considering Rattlesnake Mountain as an alternative site for a repository at the Hanford reservation? If not, why? If yes, why?

ANSWER: The Department is not considering Rattlesnake Mountain as an alternative site for the first repository at the present time. Rattlesnake Mountain was considered during an earlier evaluation and was eliminated from further consideration in favor of a deeper site in the saturated zone. Since questions about Rattlesnake Mountain continue to be asked, the Department is undergoing a three-step program. First, a report is under preparation for Rattlesnake Mountain. This report will include all available data, a summary of the information, and a listing of reasons for not using it for the first repository. Second, this report will then be compared to the DOE guidelines to see if it could be considered under the current guidelines for a repository in the unsaturated zone. Third, if the site looks like it could meet the criteria set forth in the guidelines, then field investigations could be conducted.

QUESTION: How many tons of copper would be used in a repository if that material were chosen for waste canisters? What is DOE doing to evaluate copper as a material for such canisters? What are the benefits and liabilities of using copper for such canisters?

ANSWER: The amount of copper or other material used as a waste canister material in a repository is dependent on the waste capacity of the facility and the design of the waste package (which is dependent, among other factors, on the geologic media). For a 70,000 metric ton repository capacity in basalt, a total of about 100,000 metric tons of copper would be used in producing canisters for the entire repository. This amount is about 10 percent of the 1982 total U.S. copper production.

Copper will be evaluated for the non-salt media under consideration for the first repository, along with other candidate materials, based on structural and corrosion performance, cost, availability, and fabricability. At this time, the Department is in the process of formulating the detailed plans for evaluating copper as an option for the first repository. We are currently reviewing the screening studies which led to the initial selection of candidate and alternate materials in light of recent comments concerning the performance of copper versus steel in the expected repository environments. It is expected that the current contractors involved in waste package activities at the two non-salt first repository projects will conduct the evaluation; namely, Rockwell Hanford Operations for basalt and Lawrence Livermore National Laboratory for tuff. We currently anticipate that the evaluation will occur over the next few years, consistent with the materials test program being planned for other candidate waste package materials. This program could involve the in situ testing of materials within the exploratory shaft test facilities at the candidate sites, which will not be available until the 1987-1988 time frame. The Department currently plans to initiate a waste package design and materials study for granitic host rocks in 1985 as part of the second repository program that will include an evaluation of copper.

The benefits and liabilities of copper as a canister material, based on previous material studies, are as follows:

Benefits

o Exhibits excellent corrosion resistance in very low-oxygen (reducing) repository environments.

o Pure copper (non-alloy) is not subject to certain corrosion mechanisms (simplifying assessments of long-term performance).

Liabilities

o Poor corrosion performance in oxidizing repository environments, particularly where radiation effects are non-negligible.

o Not as strong as other candidate materials (e.g., carbon steel and stainless steel).

o Capability to weld copper canisters remotely and routinely is not available in current technology.

o Cost is relatively high, compared to steels under consideration.

QUESTION: The DOE draft Mission Plan indicates that DOE will investigate in-depth the concept of the "all-purpose" self-shielded cask that could be used for spent fuel storage, transportation, and disposal (p. 2-16). According to your current plans, when would the feasibility and desirability of such a cask be determined? When is the latest time that DOE could decide to use such a cask as the basis for the MRS facility and repository system design without affecting the waste acceptance schedule included in the draft Mission Plan?

ANSWER: As part of the Systems Integration Program, DOE is planning to study the whole waste management system from the reactor to the repository. Under this program a competitive solicitation will be issued inviting industry, cask manufacturers, utilities and any other interested parties to propose new, novel ideas for improving the packaging and handling of spent fuel for the whole back-end of the fuel cycle from reactor to repository with possible storage at the reactor or elsewhere. We anticipate that the universal cask concept will be proposed for further study under this program. This program will provide a framework for comparing the technical and economic merits of different concepts on a comparable basis. The procurement document for soliciting proposals is called a Program Research and Development Announcement (PRDA) and is expected to be issued by DOE in March of 1984.

The result of these and other studies will be used to determine the packaging and handling concept best suited for the whole waste system.

Without the benefit of a complete evaluation of the universal cask concept, it is difficult to estimate the time required to resolve the different uncertainties, and evaluate the effects of this concept on the repository program. These questions should be answered as a part of the studies mentioned above.

Current estimates indicate that the waste systems studies will be completed about the end of 1986. The feasibility and desirability of the all-purpose cask should be determined by that time. At that time, the Repository program will be completing the advanced conceptual design studies for the emplacement waste package and preparing to initiate preliminary design studies. Also, at that time, the Transportation program will initiate designs for transportation casks. The all-purpose cask concept will integrate into these programs very well at that time.

If the decision to use the universal casks is made after 1987, the Repository program may experience scheduling delays in order to modify current design features of the receiving and handling facility and the emplacement equipment.

Current planning for the MRS provides for modular passive, dry storage that could include an all-purpose cask. No scheduling delays would be anticipated in the selection of this concept.

QUESTION:	The Committee has been advised of utility industry oversight groups which were organized to review DOE progress under the Nuclear Waste Policy Act. In that role, how can these groups be helpful to DOE? What continuing relationship with these groups do you anticipate?
ANSWER:	The electric utility industry has a direct interest in the success of the nuclear waste management program. They represent our clients who are paying for waste disposal services which we will provide. It is understandable and appropriate, therefore, that they have established groups to oversee DOE's implementation of the Nuclear Waste Policy Act. These industry oversight groups can contribute to the success of the program by closely reviewing our work, particularly the key decisions and reports, and sharing their assessments openly with DOE and the Congress. It is important that this process be candid so that major points of agreement, as well as major points of disagreement, are communicated. DOE has not formalized its working relationship with the industry oversight groups, nor do we believe it is necessary to do so. However, we stand ready to meet with them from time to time, schedule and workload permitting, to discuss the status of issues associated with the waste program.

QUESTION: Surely DOE is constantly evaluating their own schedule under the Nuclear Waste Policy Act, relative to the schedule provided in the Act. If at any time DOE determined that it was unable to meet the intent and substance of the Act's schedule, how soon would this Committee be advised?

ANSWER: The Department is continually mindful of its schedule for implementing the Nuclear Waste Policy Act (Act). At the present time, we are in the process of reviewing the activities of the various elements of the program for development of an updated schedule. This schedule will be incorporated into the draft Mission Plan which the Department expects to make available in April for comments, in accordance with the Act.

In regard to the intent and substance of the Act, the Department expects to meet the 1998 date to begin accepting nuclear waste. In the event that we find that this date cannot be met, the Department will promptly notify Congress of this situation, and the reasons for any delays. In the meantime, the Department intends to keep the Committee informed on the progress along the way.

QUESTION: Already we have heard that DOE considers the 1-mil levy to be inadequate. How has that been determined? How soon will Congress receive official notification?

ANSWER: DOE has made no final or formal determination that the 1 mil per kilowatt hour fee is inadequate. The discussion in our Fiscal Year 1985 budget submission reflected a preliminary budgeting concept of adjusting the fee based on inflation we were considering for reconciling our expected out year expenses with our revenue projections. However it did not constitute a formal proposal for a revision to the 1 mil fee. The Nuclear Waste Policy Act requires the Secretary to review annually the adequacy of the fee. This year's review is currently underway and is expected to be submitted to the Congress in July 1984.

Department of Energy
Washington, D.C. 20585

March 15, 1984

Honorable Marilyn Lloyd
Chairman
Subcommittee on Energy Research
and Production
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Madam Chairman:

Attached are the answers to questions on Remedial Action, Shippingport, West Valley, Three Mile Island R&D, and Commercial Low-Level R&D Program you sent after Franklin Coffman's appearance February 9 before the Science and Technology Subcommittee on Energy Research and Production.

Please note that the question on Three Mile Island also provides the information requested on page 98, line 2231, of the transcript.

The questions on the Nuclear Waste Fund and those directed specifically to Michael J. Lawrence will be coming under separate cover as soon as they are completed.

If you have any questions, please call Diana Diamond or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H. Pretorius
for Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Ms. Nancy Jeffery

POST HEARING QUESTIONS

FEBRUARY 9, 1984

SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

WITNESS, FRANKLIN COFFMAN

Questions Submitted by Congresswoman Marilyn Lloyd

Remedial Action

QUESTION: Please identify the amount of funding in FY 1985 and the total volume of material involved in the Maywood and Colonie sites under the Formerly Utilized Sites program.

ANSWER: At Maywood, New Jersey, the volume of waste from vicinity properties cleanup and waste buried onsite is estimated at 150,000 cubic yards. Our FY 1985 funding requested is $3.1 million.

At Colonie, New York, the volume of waste from vicinity properties cleanup and waste buried on the site is estimated at 30,000 cubic yards. FY 1985 funding requested is $0.4 million.

Remedial Action

QUESTION: Is the Department attempting to minimize costs at these sites by removing vicinity property contamination to the plant site and stabilizing the material in place?

ANSWER: Our plan is to remove the radioactive contamination from all of the vicinity properties and to store it on each nearby plant site in a manner that prevents further offsite contamination. We plan to take corrective actions on the plant sites as necessary to prevent further offsite contamination from the buried wastes. The congressional direction in the FY 1984 Energy and Water Development Appropriations Act was to decontaminate the plant sites as well as the vicinity properties. Our interpretation of this direction requires DOE to excavate the buried wastes and remove all wastes to another disposal site. We have informed the States of New Jersey and New York (where these plant sites are located) that, because of the large volumes of waste and the costs associated with transporting these large volumes of waste, we expect these States to select disposal locations in the State of waste origin. DOE would then propose in subsequent budget requests to acquire and construct these disposal sites in the State of waste origin. However, we also will examine the technical suitability of stabilizing these wastes in place at some of these sites and provide Congress with cost estimates and recommendations for comparison with decontamination costs.

Shippingport

QUESTION: What is the total bill for decontamination and decommissioning the Shippingport facility?

ANSWER: The total decommissioning cost is projected to be $79.7 million spread over prior years ($9.0M), FY 1985 ($16.1M), 1986 ($31.8M), 1987 ($19.5M), and 1988 ($3.3M).

QUESTION: What standards will be used for the D&D work?

ANSWER: D&D work at Shippingport will be performed to DOE standards appropriate for releasing the site for unrestricted use. These standards will assure that no member of the public could receive more than 500 millirem per year to the whole body or 1500 millirem per year to a critical organ when analyzed by conservative pathway analysis. In addition, the decontamination will be conducted to levels as low as reasonably achievable with a goal of reducing the potential whole-body dose equivalent to any member of the public to less than 10 millirem per year based on realistic pathway analysis. Physical structures remaining at the site will be decontaminated to the requirements of NRC Regulatory Guide 1.86. Materials released from the site for uncontrolled use or disposal will meet the requirements of American National Standards Institute (ANSI) standard N 13.12 for residual radioactivity and applicable standards for nonradioactive contaminants.

West Valley

QUESTION: Is the work at the West Valley site being accounted for so as to provide an easy reference to the costs of solidification of wastes as distinct from the decontamination and first-of-a-kind R&D efforts?

ANSWER: Yes. Waste solidification and decontamination costs are being accounted for in distinct categories at the second level of the Project work breakdown structure, as shown in the Schedule 47 Project data sheet budget submittal. Additionally, a technology support category is established within the waste solidification account for research and development and confirmation testing.

Commercial Waste R&D Programs

QUESTION: How much money is being funneled to the states for low level waste compact development?

ANSWER: Money is being distributed to the States for the purpose of low-level waste compact development as follows:

Recipient	Compact	Funding*/	FY
Coalition of Northeastern Governors/Northeastern Compact Process	Northeast	$ 241	1982-83
Michigan State University/ Support Development of Midwest Compact	Midwest	$ 69	1982
Midwest Council of State Governments/Midwest Compact Support	Midwest	$ 80	1983
National Governor's Association/Resource Facilitator for Regional Support and Implementation	National	$ 202	1981-83
Southern States Energy Board/Regional Management Process-Compact Support	Southeast	$ 274	1982-83
State of Washington/ Northwest Compact Support	Northwest	$ 127	1982-83
State of Colorado/ Compact Development and Issue Studies	Rocky Mountain	$ 420	1982-83
		$1,413	

*Funding in thousands of dollars.

Commercial Waste R&D Programs

QUESTION: How much funding is provided for second generation waste form development and why is this effort needed?

ANSWER: The Department is requesting funding of $1 million in FY 1985 to evaluate candidate materials and processes for a second generation waste form. The objective of this program is to develop by the year 2000 an acceptable waste form that will provide improved storage/disposal characteristics for high decay heat, high-level wastes.

The need for a second generation waste form is founded in two criteria:

1) The first generation borosilicate glass matrix waste form (in advanced stages of development) has been selected as the waste form for the relatively low decay heat West Valley and Savannah River high-level wastes. However, for high decay heat wastes, which would be generated from reprocessing relatively "fresh" spent fuel or from breeder fuel cycle high-level waste, an improved or more stable high-temperature waste form will likely be required.

2) The proposed development of a second generation waste form is estimated to require 10-15 years to complete and assure technical consensus on its adequacy. Therefore, we believe the technology should be available to store high decay heat wastes anticipated after the year 2000 and to provide a backup to the borosilicate glass matrix waste form (in the event that projected performance is not attained or the performance criteria are modified). Thus, to avoid the possible need for a very high cost, crash development effort, a more modest phased development program is recommended.

West Valley

QUESTION: In the West Valley Demonstration project, the most important step in the process could be the ceramic melter for encapsulation of the high level waste. At our present extent of knowledge, what level of confidence do you assign to that melter process? How much additional information will be necessary prior to successful demonstration of the process?

ANSWER: There is a very high level of confidence in the ceramic melter's capability to process the high-level radioactive waste. As has been discussed in the Project's Quarterly Report to Congress, a vitrification Component Test Stand using the West Valley melter design is under construction and will be completed in FY 1985. We plan to operate the melter for approximately 18 months under a variety of conditions to confirm its design and performance.

HS&T Minority Questions

QUESTION: How can we be certain that the total funds committed to the TMI program are adequate to fulfill the scope of the work?

ANSWER: It is the Department's practice in conducting the TMI-2 research and development program with General Public Utilities (GPU) Nuclear Corporation to provide specific work packages with defined milestones, rather than providing funding independent of technical progress. The pace of the Department's program matched the GPU cleanup effort through FY 1983. However, recent delays in the GPU cleanup effort have resulted in corresponding delays in the Department's research and development program. As a result, we have proposed that $2 million of FY 1984 TMI funds be reprogrammed to other Department activities. This reduces the Administration's commitment to TMI in 1984 from $37 million to $35 million. Assuming the President's budget is approved for FY 1985, we will have spent $138 million. We would expect to request the remaining $21 million in FY 1986 and FY 1987.